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Final Report

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Design Criteria for Payload Workstation Accommodations

MARTIN MARIETTA

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DESIGN CRITERIA FOR PAYLOAD WORKSTATION ACCOMMODATIONS STUDY

Prepared for

National Aeronautics &
Space Administration

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FOREWORD

The contract effort was to assess anticipated Shuttle Sortie payload man-system design criteria needs and to address those needs which Skylab experience cannot be expected to fulfill. The Phase I effort derived a listing of anticipated man-system interactions for the scientific disciplines. The Phase II effort assessed the extent to which documented Skylab experience might be expected to provide system design guidance for each of the identified interactions. Where the analysis revealed the reduced Skylab data in design criteria form does not answer the anticipated needs, candidate criteria, based on unreduced Skylab data, available prior research, original analysis, or related requirements derived from previous space programs, are provided.

The Final Report is submitted in accordance with the requirements of Contract NAS8-30952 Statement of Work, Paragraph 3.B, REPORTS REQUIREMENTS.

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I. STUDY SUMMARY

The Phase I investigation and analysis resulted in the identification of 14 anticipated man-system interactions applicable to the variety of payloads in the ten scientific disciplines. They were identified as follows:

1. Experiment Setup - Direct
2. Experiment Start/Stop
3. Monitoring at C&D Panel
4. Experiment Control - Direct
5. Experiment Control - Remote
6. Direct Experiment Observation
7. Remote Experiment Observation
8. Housekeeping
9. Maintenance
10. Calibrate Instrumentation
11. Data Reduction/Analysis
12. Remote Pallet Operations
13. Free Flying Teleoperator Operations
14. Subsatellite Operations

These man-system interactions were the basis for the comprehensive Phase II detailed assessment of existing man-system design criteria. MSFC-STD-512, MSFC Man-System Design Criteria for Manned Orbiting Payloads and the applicable portions of MIL-STD-1472, Human Engineering Design Criteria for Military Systems, Equipment and Facilities, represented the existing documented experience expected to provide design guidance for Sortie payloads. Each section of MSFC-STD-512 was assessed with each of the man-system interactions to determine applicability and completeness of the criteria.

MSFC-STD-512 establishes a reasonably complete design criteria baseline for payload workstation accommodations. Recommended new/additional criteria are identified fulfilling the primary study objective. Additionally, a few new and unique

requirement needs are noted which will require further definition and/or resolution of specifics. Significant discrepancies and deficiencies to existing requirements and organizational structure were annotated and are summarized herein.

II. PHASE I SUMMARY

The results of the Phase I study are reported in the Phase I Technical Report, Shuttle Payload Needs versus Skylab Data Analysis, MCR-74-377, October 1974. Pertinent data and conclusions are documented as part of this final report to complement and give continuity to the Phase II effort.

Although there has been, and undoubtedly will continue to be, considerable evolution of the identified Sortie payloads, these payloads are divided into ten distinct scientific disciplines as follows:

1. Astronomy (AS)
2. High Energy Astrophysics (HE)
3. Solar Physics (SO)
4. Atmospheric and Space Physics (AP)
5. Earth Observation (EO)
6. Earth and Ocean Physics (OP)
7. Space Processing Applications (SP)
8. Life Sciences (LS)
9. Space Technology (ST)
10. Communications and Navigation (CN)

The Summarized NASA Payloads Descriptions, Sortie Payloads, June 1974, (Level A), document lists a total of 96 payloads but fails to provide a level of detail necessary to accomplish an analytical examination of each experiment for establishing payload accommodations design criteria.

The Payloads Descriptions, Volume II, Sortie Payloads, June 1974 - Preliminary Review Copy, Level B, contains additional detail for 27 of the 96 payloads. With the concurrence of NASA, this document was primarily used for detail analyses during Phase I on the assumption that the crew activities for the 27 payloads are representative of the others within a given scientific discipline.

Table 1 provides a breakdown of the 96 payloads by discipline and the particular payload mode of each discipline. Table 2 provides a similar breakdown of the 96 payloads, this time comparing the particular scientific discipline to its control mode. Such categorization of payloads served to establish the major areas of emphasis for the Sortie payloads configurations and revealed the trend of man-system interactions for each scientific discipline.

For the purposes of this study, a workstation was defined as any location in the Shuttle Transportation System at which a task or activity relating to payload experiments is performed. It does not include locations where activities unrelated to experiment operations are accomplished; e.g., commander and pilot flight positions, or middeck crew accommodations area where food, waste management and sleep facilities are located. Crew locations on the Orbiter flight deck, such as the payload specialist, mission specialist and manipulator control stations, are workstations, as are most of the locations in the Spacelab pressurized module. The mission specialist station was not listed as an applicable workstation because its primary function deals with monitoring of Orbiter and Spacelab subsystems and facilities; therefore, it was not considered as being Sortie payload unique. The Spacelab pallet is a workstation for EVA only. Nine workstations were identified in the Orbiter and Spacelab. They are:

1. Payload Specialist Station (Orbiter PSS)
2. Remote Manipulator Station (Orbiter RMS)
3. Spacelab Workbench/Console (Core Segment)
4. Spacelab Airlocks
5. Spacelab Window/Viewing Ports
6. Specialized Experiment Locations (Spacelab)
7. EVA Locations
8. Stowage Locations
9. Spacelab Consoles (Experiment Segment)

Table 1 Sortie Payloads Versus Payload Mode

Experiment Discipline \ Payload Mode	Pallet Only	Module Plus Pallet	Module Only	Carry On
Astronomy	31			2
High Energy Astrophysics	12			
Solar Physics	3			
Atmospheric & Space Physics		1		
Earth Observations	2	1	1	
Earth & Ocean Physics	1	4		
Space Processing Applications	3	8	4	
Life Sciences		1	1	1
Space Technology	4	5	2	1
Communication & Navigation	1	6	1	
Total	57	26	9	4

Table 2 Sortie Payload Control Mode Summary

Experiment Discipline \ Control Mode	Ground	Orbiter	Spacelab	Ground/ Orbiter	Spacelab/ Orbiter	Passive
Astronomy	7	4		21		
High Energy Astrophysics	8			4		
Solar Physics		2		1		
Atmospheric & Space Physics					1	
Earth Observations		2	1		1	
Earth & Ocean Physics		1	4			
Space Processing Applications		3	12			
Life Sciences			2		1	
Space Technology		4	6		1	2
Communication & Navigation		1	7			
Total	15	17	32	26	4	2

A detailed analysis of the 27 payloads revealed the anticipated man-system interactions. Table 3 lists and defines 14 man-system interactions which will occur at the payload workstations. The definitions are general in the sense that they could apply to any payload operation in any discipline, but specific in differentiating between the types of man-system interactions which may take place. For example, remote and direct experiment observation or control were defined separately, based primarily on the level of human activity in each case. Each separate man-system interaction involves a wide range of specific tasks, all of which relate to the definitions presented. It is understood that other definitions could be utilized, but the breakdown chosen, although arbitrary, is workable. Table 4 presents an analysis of the occurrence of man-system interactions for each of the 96 payloads, including Level A and B descriptions, and is based upon best engineering judgement.

Based on the analyses supporting the establishment of anticipated man-system interactions, specific operational trends and conclusions can be substantiated for each of the scientific discipline payloads, as follows:

1. <u>Astronomy, High Energy Astrophysics and Solar Physics</u> - Because these payloads are pallet only, crew interactions for these disciplines are concentrated primarily in the area of monitoring and remote observation from the Orbiter PSS workstation. Experiment specialists on the ground will direct the efforts of the crewmen for the majority of the experiments. Therefore, the crew will act primarily as "operators" and not as scientific discipline experts. Specialists for particular payloads may comprise part of future crews at which time primary expertise will be onboard. There are limited housekeeping tasks, but in

Table 3 Man-System Interaction Definitions

Man-System Interaction	Definition
EXPERIMENT SETUP - DIRECT	Crewman physically moves equipment/experiment from stowage to operation location, configures support systems (prep and post) and returns equipment to stowage after experiment completion.
EXPERIMENT START/STOP	Crewman initiates and terminates experiment operations.
MONITORING AT C&D PANEL	Monitoring experiment/payload status at display panel in Orbiter (PSS) or Spacelab module; minimal crew activity.
EXPERIMENT CONTROL - DIRECT	Crewman mechanically or electronically controls experiment directly (adjust, select modes, identify/acquire targets, react to data, etc.); crewman and experiment are in the same physical location.
EXPERIMENT CONTROL - REMOTE	Crewman electronically controls experiment indirectly; crewman and experiment are physically separated.
DIRECT EXPERIMENT OBSERVATION	In situ observation of experiment progress; crewman and experiment are in the same physical location.
REMOTE EXPERIMENT OBSERVATION	Observation of an experiment physically located away from crewman (i.e., crewman in Orbiter, experiment on pallet); observation either thru viewport/window or TV system.

Table 3 Man-System Interaction Definitions (Cont'd)

Man-System Interaction	Definition
HOUSEKEEPING	Crewman performs activities such as film or tape changing, store/dispose of throw away items, general cleanup, etc.
MAINTENANCE	Unscheduled or scheduled repair or service activities performed directly (shirtsleeve), remotely (shirtsleeve with manipulator or free flying teleoperator) or EVA.
CALIBRATE INSTRUMENTATION	Crewman performs procedures (direct or remote) to calibrate or recalibrate instrument prior to or after experiment data take.
DATA REDUCTION/ANALYSIS	Crewman reviews experiment data and determines next experiment functions based on that data; redirects emphasis of experiment as necessary.
REMOTE PALLET OPERATIONS	Display/align/retract booms or antennas on pallet mounted equipment; activities controlled from Orbiter or Spacelab module.
FREE FLYING TELEOPERATOR OPERATIONS	Checkout, deploy, track, operate (precise on-orbit control from FFTO panel) and retrieve; TV system observation utilized to perform remote tasks.
SUBSATELLITE OPERATIONS	Checkout, deploy, track, operate (majority of control from ground - on-orbit, control from PSS), and retrieve; observation thru window or TV system.

Table 4 Man-System Interactions by Payload

Payload \ Man-System Interaction	Monitoring at C&D Panel	Direct Experiment Observation	Remote Experiment Observation	Experiment Start/Stop	Experiment Control-Direct	Experiment Control-Remote	Housekeeping	Experiment Setup-Direct	Maintenance	Subsatellite Operations	Free-Flyer Operations	Remote Pallet Operations	Data Reduction/Analysis	Calibrate Instrumentation
AS-01-S	X		X										X	X
AS-03-S	X		X											
AS-04-S	X		X										X	X
AS-05-S	X		X	X		X						X		
AS-06-S	X		X	X										
AS-07-S	X		X	X		X								
AS-08-S	X		X											
AS-09-S	X		X	X		X		EVA				X		
AS-10-S	X		X	X		X								X
AS-11-S	X		X	X		X								X
AS-12-S	X		X	X		X								
AS-13-S	X													
AS-14-S	X		X	X		X								
AS-15-S	X		X	X										
AS-18-S	X		X	X		X				X		X		
AS-19-S	X		X	X		X								
AS-20-S	X		X	X		X								
AS-31-S	X		X	X		X								
AS-41-S	X		X	X		X								
AS-42-S	X		X	X		X								
AS-43-S	X		X	X		X				X		X		
AS-44-S	X													
AS-45-S	X													
AS-46-S	X		X	X		X								
AS-47-S	X													
AS-48-S	X		X	X		X								X
AS-49-S	X		X	X		X				X		X		
AS-50-S	X		X	X		X								
AS-51-S	X		X	X		X								X
AS-54-S	X		X											
AS-61-S	X													
AS-62-S	X		X											
AS-01-R	X	X	X	X		X			EVA/IVA			X		
HE-11-S	X		X											
HE-12-S	X		X											
HE-13-S	X		X											
HE-14-S	X		X											
HE-15-S	X		X											
HE-16-S	X		X											
HE-17-S	X		X											
HE-18-S	X		X											
HE-19-S	X		X											
HE-20-S	X		X											
HE-03-R	X	X	X	X		X			EVA			X		
HE-11-R	X	X	X	X		X			EVA			X		
SO-01-S	X		X	X		X	TAPE					X	X	
SO-11-S	X		X	X		X	TAPE						X	
SO-12-S	X		X	X		X						EVA/ FILM	X	
AP-06-S	X		X	X		X				X		X	X	X
EO-01-S	X	X		X	X		X	X					X	X
EO-05-S	X		X	X		X		EVA	X			X		
EO-06-S	X		X	X		X			X			X		
EO-07-S	X	X	X	X	X	X	X	X				X		
OP-02-S	X	X	X	X	X	X	X	X				X	X	X
OP-03-S	X		X	X		X	X					X	X	X
OP-04-S	X		X	X		X	X							
OP-05-S	X	X	X	X	X	X	X	X				X	X	X
OP-06-S	X	X	X	X	X	X	X	X				X	X	X

Table 4 Man-System Interactions by Payload (Cont'd)

Payload \ Man-System Interaction	Monitoring at C&D Panel	Direct Experiment Observation	Remote Experiment Observation	Experiment Start/Stop	Experiment Control-Direct	Experiment Control-Remote	Housekeeping	Experiment Setup-Direct	Maintenance	Subsatellite Operations	Free-Flyer Operations	Remote Pallet Operations	Data Reduction/Analysis	Calibrate Instrumentation
SP-01-S	X	X	X	X	X	X	X	X					X	
SP-02-S	X	X	X	X	X	X	X	X					X	
SP-03-S	X	X	X	X	X	X	X	X					X	
SP-04-S	X	X	X	X	X	X	X	X					X	
SP-05-S	X	X	X	X	X	X	X	X					X	
SP-12-S	X		X	X		X								
SP-13-S	X		X	X		X								
SP-14-S	X	X	X	X	X	X	X	X					X	
SP-15-S	X		X	X		X								
SP-16-S	X	X	X	X	X	X	X	X					X	
SP-19-S	X	X	X	X	X	X	X	X					X	
SP-21-S	X	X		X	X		X	X					X	
SP-22-S	X	X		X	X		X	X					X	
SP-23-S	X	X		X	X		X	X					X	
SP-24-S	X	X		X	X		X	X					X	
LS-04-S	X		X	X		X			EVA		X	X		
LS-09-S	X	X		X	X		X	X					X	X
LS-10-S	X	X		X	X		X	X					X	X
ST-04-S	X	X	X	X	X	X	X	X						
ST-05-S	X	X		X	X		X	X						
ST-06-S	X	X		X	X		X	X						
ST-07-S	X		X	X		X						X		
ST-08-S*	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ST-09-S	X		X	X		X								
ST-11-S	X		X	X		X								
ST-12-S*	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ST-13-S	X		X	X		X						X		
ST-21-S	X	X	X	X	X	X	X	X				X	X	X
ST-22-S	X	X	X	X	X	X		X				X	X	
ST-23-S	X	X	X	X	X	X		X				X	X	
CN-04-S	X	X	X	X	X	X	X	X					X	X
CN-05-S	X		X	X	X	X							X	
CN-06-S	X		X	X		X								
CN-07-S	X		X	X		X						X		
CN-08-S	X		X	X		X						X	X	
CN-11-S	X		X	X		X						X		
CN-12-S	X		X	X		X								
CN-13-S	X		X	X		X								

*Totally passive payload

general, these three scientific disciplines involve the least amount of crew activities except for planned repair/resupply EVA's on revisit missions.

2. Atmospheric and Space Physics - This discipline utilizes the module plus pallet with on-orbit control. There are several workstations and a diverse number of interactions involved in the conduct of these experiments, including subsatellite deployment from the Orbiter Remote Manipulator Control Panel and deployment of booms and antennas. The crew will have direct control of experiment operations as well as direct interface with a broad spectrum of experiment hardware. Inflight maintenance may be necessary; however, it is not defined at this time.

3. Earth Observations - This discipline utilizes all three Shuttle payload modes and these are controlled on-orbit from several workstations. There is a high degree of direct crew involvement and interaction with various types of hardware. Planned and contingency EVA, as well as inflight maintenance, are specified for these payloads.

4. Earth and Ocean Physics - These payloads utilize both pallet only and module plus pallet with on-orbit control from several workstations, including viewports and airlocks. All payloads have contingency EVA and inflight maintenance specified. This discipline has a wide range of crew interactions resulting in a heavy crew involvement. Microwave radiation is specified as a potential hazard.

5. Space Processing Applications - This discipline employs all three payload modes with on-orbit control. There are varying degrees of crew interactions; i.e., from complete payload control and operation to simply monitoring automated experiments. There

are no EVA's or inflight maintenance specified. Potential hazards are fire and electrical shock confined to a selected species of high voltage payload hardware.

6. Life Sciences - This discipline is unique from the other scientific disciplines in that it contains three different and distinct payload types, utilizing the module plus pallet and module only mode. All are controlled on-orbit.

a. Free Flying Teleoperator (FFTO) - Control and utilization of a remotely controlled vehicle which can perform experiment and maintenance functions involves several unique combinations of crew interactions. Maintenance operations of the FFTO conducted in conjunction with a crew EVA will be evaluated. Primary control of the FFTO will be maintained from the Orbiter and crew experience with free flyer operations will be required.

b. Life Sciences Shuttle Laboratory - This payload utilizes the largest module configuration available and incorporates many unique types of experiment equipment. Crew activities are extensive and involve such test items as an internal centrifuge, animal housing units (vertebrates and invertebrates) and biomedical analyzers. Both planned and contingency EVA and IFM are specified. Specialized equipment, such as a surgical table and the centrifuge, present significant procedural and safety problems. Crew control and on-board data reduction/analysis is critical for these payloads.

c. Carry-On Laboratories - Although detailed equipment descriptions for the carry-on labs are not available, the extent of crew interactions can be defined. These experiments can be conducted either in the Orbiter or Spacelab, with crew participation ranging from simple monitoring to direct control. EVA or IFM are not specified.

7. Space Technology - All payload modes are employed by this discipline and control is maintained on-orbit. The level of crew interactions for these payloads is similar to that for the space processing payloads, except that the degree of automation for pallet only payloads is not quite as complete.

8. Communications and Navigation - This discipline employs the three major payload modes with on-orbit control. Planned EVA is specified for one payload, but is not defined. Crew interactions center around utilization and monitoring of various electronic systems. Spare components kits are identified as part of the experiment equipment, but IFM plans are not defined.

III. PHASE II DETAIL STUDY

The 14 man-system interactions derived during Phase I provided the basis for the assessment of existing man-system design criteria versus man-system interactions. During Phase II, MSFC-STD-512 and the applicable portions of MIL-STD-1472 represented the existing documented experience expected to provide design guidance for Sortie payloads. The subsequent detailed analyses performed were aimed at the basic objective of identifying man-system design criteria, usable by design engineers, that does not duplicate existing criteria.

The initial step was to determine which portions of MSFC-STD-512 influence the design provisions for each of the man-system interactions. Each section of MSFC-STD-512 was assessed with each of the man-system interactions to determine overall applicability. The assignment of each section to the man-system interactions is contained in matrix form in Appendix I. The matrix contains the initial analysis and was verified during the Phase II detailed assessment. The preceding analyses immediately indicated certain sections of MSFC-STD-512 which were not applicable to this study. Further investigation into the specific requirements of these sections confirmed they were either "program" defined (i.e., spacecraft pressure, temperature, humidity) or affected the crew provisions not associated with the payload workstations determined in Phase I. The sections specifically excluded from further assessment were:

Section 2	General Environment - Interior Spacecraft
Section 2.1	Atmosphere Composition and Pressure
Section 2.2	Atmosphere Temperature and Humidity
Section 2.3	Atmosphere Ventilation
Section 3.7	Habitability (except for 3.7.4.2, 3.7.5.1, 3.7.6.1, 3.7.6.2, 3.7.7.3, 3.7.8.3 and 3.7.9)

Section 6.3	Fire Protection and Control
Section 6.4	Leak Detection and Control
Section 6.5	Caution and Warning Systems
Section 7	Zero-Gravity Simulation
Section 7.1	Simulation

The next step combined the occurrence of man-system interactions for each of the 96 payloads identified during Phase I (Table 4) with the MSFC-STD-512 sections applicable to the man-system interactions (Appendix I), thereby determining the criteria applicable for each payload. An assessment attempt was made to verify the applicability and completeness of the MSFC-STD-512 design criteria to each of the 96 payloads. The results of this approach proved to be marginal. Sufficient specific hardware details regarding physical and operational characteristics for experiments within a given payload are not available in any type of documentation. Identification of the applicable design criteria for each payload was misleading as many cargoes are comprised of individual experiments from several scientific disciplines. Considering only the 30 payloads (an increase of 3 since Phase I) with Level B descriptions, the result is a potential combination of 189 different, individual experiments. In the case of dedicated missions, analysis becomes more meaningful because only that particular payload and applicable design criteria has to be considered.

To further ensure the completeness of the assessment, an analysis was performed combining the man-system interactions and associated design criteria for every payload within each scientific discipline as discussed in the previous paragraph. The results represent the applicability of each section of MSFC-STD-512 to each of the ten scientific disciplines and are presented in matrix form in Appendix II. Spacecraft Maintenance

and Extravehicular Activity were found to be applicable to only 40% of the scientific disciplines. Other than these two categories, the remaining applicable portions of MSFC-STD-512 effect 70-100% of all scientific disciplines. This matrix shows that Astronomy (AS), High Energy Astrophysics (HE), Earth Observation (EO), and Life Sciences (LS) are the four payload scientific disciplines requiring the largest amount of interaction and compliance with MSFC-STD-512. Appendix II indicates a uniform trend among the scientific disciplines regarding the applicable design criteria. At this point, it was determined that a complete assessment of existing design criteria could be accomplished predicated on:

1. Familiarity with the functional details (crewman activities) associated with each of the man-system interactions;

2. Required crew interfaces with operational and experiment hardware based on past experience.

MSFC-STD-512 was found to provide reasonably complete design criteria for payload workstation accommodations. This conclusion is based on the determination that valid man-system design criteria documentation is intended to apply to all future manned space programs in a general sense--providing that criteria are necessary to enhance man's role in space flight. To this end, the remaining portions of this report contain recommended new/additional requirements and refinements which would improve the overall quality of existing design criteria fulfilling the primary Phase II study objective.

At the other end of the spectrum, specifying component level of detail criteria compounds the complexity of documenting man-system design criteria. This principle encompasses the theory

that man-system design criteria should fulfill the needs for all mission standard and unique designs. Space Shuttle Program payloads will be introducing new and unique hardware concepts (both operational and experimental) which are entirely beyond the scope of previous experience; i.e., lasars, internally generated radiation, micro-organisms, live viruses, hazardous chemicals and biologicals, remote manipulators, etc. Supplemental criteria aimed at program uniqueness and component detail may be in order to specify the ultimate intent of man-system design criteria. Further analytical studies and future refinements to MSFC-STD-512 should consider the definition of man-system integration involvement and determine whether firm requirements or guidelines are necessary to support the activity.

A. Recommended New/Additional Criteria

Existing design criteria was reviewed in detail for its applicability and completeness as it relates to Sortie payloads. Additional documentation (mission evaluation reports, crew debriefings, experiment reports, etc.) was researched and reviewed striving for additional, valid criteria and stimulus aimed at fulfilling the Phase II primary objective. The recommended new/additional criteria identified during Phase II are listed for consideration as future inclusions to MSFC-STD-512.

- Mobility aids should be located as close as possible to equipment thereby keeping "torque forces" and "opposite forces" as close together as possible.
- Fixed mobility aids should protrude above equipment for easier accessibility.
- Adequate provisions for foot restraints and temporary equipment restraint are necessary at all workstations. Sizeable surfaces (e.g., wall space) around a workstation should provide temporary equipment restraint provisions.
- Handholds as mobility aids are required in large open areas at translation destination points. Mobility aids between destination points are not required unless a change in translation direction is required.
- Handholds should be provided as mobility aids at transition points in the spacecraft.
- Foot restraint provisions should be provided at all possible worksites. When provided, in general, handholds are not necessary as restraint provisions in areas where work is performed because most work in zero-g requires the use of both hands.

- Equipment items are used as mobility aids; therefore, allowances for this fact should be considered during design.
- Crewman restraint provisions, other than foot restraints, are generally unnecessary at workstations.
- A torso restraint, in addition to a foot restraint, may be required when performing tasks that call for the maintenance of a body position other than the relaxed zero-g body position.
- Design limit loads for the EVA application of the Portable Foot Restraint should be specified.
- The EVA fixed foot restraint should specify a stand-off distance (placement) from the workstation.
- EVA foot restraints and handrails should be provided in the vicinity of critical items (thrusters, solar arrays, charger battery regulator modules (CBRMs), lights, etc.) for contingency maintenance needs.
- Where crew translation through passageways can be accomplished in an erect orientation, one-g type doors should be provided (instead of porthole type openings) to eliminate unnecessary attitude changes during translations.
- Equipment items, especially equipment items with small surface areas, create mobility hazards and should not protrude into traffic areas.
- Work locations, delicate panels or other delicate equipment should not be located near or protrude into translation areas of the spacecraft because translations, in general, tend to be less accurate in zero-g than in one-g.

- Adequate protection devices should be provided for crewman/equipment if equipment must be located along a mobility route.
- Padding shall be provided around hatches and transition areas of the spacecraft to protect the crewmen from bruising impacts.
- Work surfaces should be chest high and control and display panels should be oriented for the relaxed zero-g neutral body position (reference MSFC-STD-512, 3.2.3.2).
- Lighting configuration controls for C&D panels should be available at photography worksites so that activities with lighting constraints do not impact other simultaneous activities.
- When open structure (triangular grid for example) is used for floors, ceiling or compartmental division, a means should be provided (e.g., using a fine mesh screen between the structure) for closing-off compartments to prevent the loss of loose items as a result of "floating."
- There should be additional specifics given relative to the switch guard height requirements for toggle switches, rotary switches and thumbwheel switches. Perhaps the requirement could be stated thusly: Switch guard heights shall be a minimum of (25-50%) higher than the protrusion of the switch it is protecting.
- All restraining devices, cable or wiring harnesses and umbilicals which may restrain a human operator or test subject shall include quick disconnect or rapid release devices to free the operator or subject under adverse conditions.

- All quick disconnect or rapid release mechanisms used to free a human operator or test subject from any restraining device, cable, wiring harness or umbilical shall automatically remove power or render inoperative all equipment acting upon or used by the test subject or operator for all modes of equipment operation.
- In areas where many small components with similar names or shapes are utilized, there should be a picture or sketch for each item at their use location.
- Initial design concepts need to include inflight maintenance provisions concurrent with hardware design and development.
- Design criteria for maintainable spacecraft must include provisions for extra-vehicular inflight maintenance. These criteria must ensure that translation and restraint capability is provided for all potential work areas; i.e., predetermined attaching points for handrails, restraints, and tethers.
- Only fine mesh screens should be provided on air intake screens. Consideration should be given to replaceable (cloth) screens to facilitate housekeeping chores.
- All spacecraft equipment items that will require cleaning shall be designed to facilitate cleaning.
- Specific tool access/clearance requirements for EVA should be specified to the same detail as IVA.
- Special attention should be given to both the location and size of windows and the design of surrounding areas. Design should optimize arrangement for continuous out-of-

window visual tasks and provide sufficient camera mount provisions. Consideration should be given to a large, dome shaped window design with a circumferential restraint around it that would enable a crewman to assume any desired body position in the 360-degree range.

- Diffusers should be capable of being swiveled to enable better airflow directional capabilities.
- Air vent adjustments (control provisions) should be accessible to the crewman while inside the sleep restraint.
- Trash generation areas should be closely evaluated during training to identify optimum placement of containers or receptacles in the flight vehicle.
- Stowable items should have dedicated stowage locations and items to be stowed should have their nomenclature and stowage location identified on them.
- Writing surfaces should be provided on the lids or doors of stowage lockers for the purpose of listing the locker's stowage additions/deletions.
- Retractable cable caddies should be provided for all cables and hoses; color or pattern coding should be provided to help differentiate among the various types of cables and hoses.
- Items stowed in drawers should be identified by labels placed on the exterior of the drawer to indicate the drawer's contents.
- All flat door surfaces in the spacecraft should have springs or other devices for the temporary restraint of equipment, checklists, etc.

- Assembled pressure suits should be allocated more stowage volume in zero-g than in one-g because, in zero-g, assembled suits assume the shape of a full-sized body.

- Pressure suit donning stations should provide adequate working volume for two men in addition to foot and equipment restraint provisions.

- A workstation should provide the operator the most desirable work position, and a common operator orientation among all workstations is not necessary but desirable.

- Providing different orientations among various spacecraft modules can produce momentary visual disorientations when translating among modules. A consistent orientation among modules facilitates orientation.

- Effective utilization of available space should be the primary design criterion for workstation design; the hardware for any work station should have a consistent orientation relative to the orientation of the operator.

- Scientific Airlock - Requirements would be limited in scope to operational procedure decals/markings, safety interlocks, and emergency characteristics; i.e., backup design features which could be utilized in special cases which would be beyond the scope of normal operation.

- Vacuum Outlet Systems - Criteria should include:

  - Access to a space vacuum shall be provided for the overboard dumping of fluid and vapor waste products.

  - Each line in the vacuum system shall have a shutoff valve.

- Each valve shall:

  1. Have a permanently attached handle.
  2. Be clearly marked with the system it vents.
  3. Be clearly marked with "OPEN/CLOSED" indicies.

- Each handle shall be protected or be equipped with a locking feature to prevent inadvertent actuation.

- Operating forces for the shutoff valves shall not exceed 111 N (25 pounds) lateral force or 200 N (45 pounds) pull.

B. Design Considerations/Preferences

In the course of assessing the applicability and completeness of MSFC-STD-512 to Sortie payloads and while reviewing additional related documentation, there seemed to be more than just a list of "do's" in the form of firm design criteria/requirements. There are additional data which have been overlooked or perhaps not even given serious consideration for documentation in the past. These are the vast quantities of design data information in the form of crew debriefings and objective evaluations of the various systems/experiment hardware. These sources contain a wealth of information which would be helpful to design engineers -- it could provide them with not only a list of "do's" but also would interject into their thinking "clues" for overall design improvements in the form of opinions, recommendations, philosophies, preferences, etc., which cannot be stated as hard, firm design requirements but in their own way would be equally important as stimuli for designers to strive for design improvements and refinements. They could possibly be labeled as "Informal Considerations" or "Personnel Preferences." Data falling into this category are also recommended for inclusion in MSFC-STD-512 to further assist document users.

- It has been successfully demonstrated that certain kinds of off-the-shelf hardware -- with primarily external modifications to meet flammability requirements -- can be utilized effectively in a zero-g environment.

- An open grid ceiling and floor provides some outstanding design features, such as foot restraint flexibility and the nonrestriction of environmental airflow among various compartments. However, there are also some minor problems with this design. Equipment stowed on the floor interferes

with the capability to use all of the openings for restraint purposes and the grid could be slightly larger for easier hand accessibility for debris removal. Consideration should be given to various shaped grids (triangular, rectangular, hexagon, etc.) and removable grid panels to enhance accessibility for debris removal/inflight maintenance and allow for increased work volume envelopes.

- Volume requirements for crew compartments in zero-g are basically the same as volume requirements in one-g. The increased ability to use three dimensional space in zero-g does not significantly effect a perceived reduction in compartment volume requirements.
- One-g and radial arrangements can be equally effective in zero-g. Two Skylab crews tended to agree that both arrangements are equally effective inflight but that one-g arrangements are better for ground training and test. The other Skylab crew stated a greater preference for one-g orientations, primarily because of the better foot restraint provisions and flexibility.
- Bungees work more adequately if they are stretched across a convex surface.
- Fixed soft foot restraints should have soft, easily pliable material rather than the fire proof type material as used on Skylab. They should also be large enough to accommodate various types of footwear worn inflight. They are adequate for limited-use situations.

- More than one type of wearable foot restraint should be provided for each crewman. It would be preferable to provide several pairs of shoes with attached restraint interchangeability. Shoes should have zipper-type fasteners rathor than lace-type for ease of donning and doffing. Also, a reinforced toe cap should be provided.
- Foot restraint provisions around lockers in large volume open areas are handy but not absolutely required. Unstowing and stowing of various sized equipment items can be accomplished in zero-g by use of hands only.
- Fixed foot restraints should not be placed so that they interfere with drawer openings.
- Soft material padding on zero-g chairs appears to be desirable.
- Chair-type restraints are totally unnecessary.
- A rigid mobility aid (fireman's pole) is preferable to a soft mobility aid (long strap) in large open volume areas. However, in the large open forward-dome area of the Skylab OWS, mobility aids (fireman's pole and long strap) were used by crews only during the initial portion of the missions (one to two weeks). After the crews became adept to translating in zero-g, the mobility aids were disconnected and stowed for the remainder of each mission.
- The requirement for mobility aids varies as a function of compartment volume. In smaller volume compartments, mobility aids are used extensively because translational maneuvers are accomplished predominately by the use of hands.

- The triangle shoes/triangular grid restraint concept is an outstandingly good system providing excellent restraint provisions. It is recommended for future spacecraft applications; however, consideration should be given to custom-designed restraints and other restraint concepts for future applications.

- Enough temporary equipment restraint provisions, such as velcro and snaps, can never be provided.

- Except for initiating soaring type translations, the legs are sort of "along for the ride" in zero-g. The legs and feet often impact equipment located long a mobility route.

- Open triangular grid surrounding an opening between compartments can be a potential mobility hazard. Injury could occur if a crewman catches a finger in the open grid during translation.

- Three factors contribute to the difficulties of stowage management: the complexity of the design of stowage accommodations, the lack of dedicated stowage locations for numerous equipment items, and the lack of standardization in the various types of door latches and fasteners. The design goal for stowage lockers should be simplicity of design with simple equipment item restraints inside.

- In a 5-psi, zero-g environment, mosite inserts in drawers do not provide adequate retention provisions because large items are generally difficult to remove from mosite cutouts while small items tend to float free. However, in a 14.7-psi zero-g environment, analysis indicates mosite may be adequate.

- Consideration should be given to providing one or two dresser drawer type stowage areas, preferably in the sleeping area, so that crewmen can use them for storage of various items carried around in pockets. These drawers should be launched empty and provide internal restraint provisions.
- Decals (indicators) should not be placed on a foot restraint area. Joint utilization of a restraint area should be avoided.
- Near sleep restraints, dimmable incandescent-type light rather than fluorescent light is preferred.
- Zero-g spacecraft housekeeping requirements are not really different from those that would be required in a similar closed environment in one-g. Neither are housekeeping tasks any more difficult to perform in zero-g; in fact, in most cases, they are easier.
- Fluid spillage is not a major problem but clean-up is more difficult in zero-g because of greater dispersion of droplets. The Skylab crews resorted to the use of used clothing articles as rags for fluid clean-up and found that the towel wicking action was very effective in zero-g. Consideration might be given to providing clean-up items having high absorption capability.
- Careful consideration should be given to garbage management, especially the requirements for the treatment and disposal of food wastes. It has proven to be both time consuming and bothersome.

- On Skylab, spacecraft cleanliness was not a problem; the need for extensive cleaning never materialized. Impromptu cleaning was preferred over cleaning-by-schedule as had been initially planned.
- A handle/holder for biocide wipes to keep the iodine off the hands or the use of a non-staining biocide should be considered for future missions.

C. Organizational Structure

Present organizational structure makes MSFC-STD-512 somewhat difficult to use. Four main categories seem to be the cause. These are:

1. The repetition of design criteria throughout the document.

2. The difficulty involved in locating the exact criteria when referenced to other sections of the document, primarily because of incomplete alphanumerical listings and use of "bullets" for specific criteria.

3. The division of criteria in different sections of the document which should be combined under one section.

4. The anonymity of certain criteria as a result of being contained in sections that might make it difficult for the user to locate.

The following explains in further detail, with examples, the meaning of each of these:

1. Repetition of Design Criteria - Throughout MSFC-STD-512, there are repeats of criteria in various sections which could be combined instead of restating them. For example:

- There are common criteria for hand-operated and tool-operated fasteners contained on Pages 3-30 and 3-43.
- The requirements for nomenclature location Page 3-103 are also part of Markings and Labels on Pages 3-116 and 3-117.
- Requirements under Auxiliary Equipment on Pages 3-142 3-143 are also covered under Crew Accessories on Page 3-190.
- Criteria on Page 3-187 for Atmosphere Microbiological Contamination Control are essentially repeats from

Page 2-11 under Atmosphere Ventilation and Odor and Particulate Control on Page 3-168.

2. Incomplete References -

- Under "Examples" on Page 2-11, the reference to Section 3.7.4.1 involves a total of 16 pages, leading the user on a "witch hunt." The reference should be more specific to save the user time and effort.
- Reference under Portable Lights, Page 2-15, should be 6.2.3.3 instead of 6.2.4.
- Reference under Throw-Away Launch Restraints to Section 3.5, Markings and Labels, should be Section 3.5.1, Discardable Items.
- Reference for adequate clearance envelopes, last requirement on Page 3-61, is to Section 3.2.2.2, which is 12 pages long and to Section 3.2.2.3, which in turn refers the reader to Section 5.2.5.
- Under Transfer Methods and Devices on Page 3-63, there is a reference to Section 3.2.2.1 for Temporary Restraint Techniques which doesn't exist under that title.
- On Page 3-123, under Display Brightness Control, the reference to MIL-STD-1472, Paragraphs 5.2.2.1.9 and 5.2.6.6.3 have nothing to do with the subject requirement.
- Reference to Section 3.5.2 under Symbology on Page 3-125 is incorrect. It doesn't say anything about Symbology.
- Section 3.6.4.1, Paragraph f reference to MIL-STD-1472, Section should be 5.4.1.6.

- Reference under "Examples" column on Page 3-160 to Paragraph 3.7.6.2 should be 3.7.6.2.a.

- Under 3.7.6.2.c on Page 3-185, reference is made to Section 2.3.2.3 for specific requirements and example design solutions associated with contaminant control. The referenced section contains data on this subject, but there are also other sections throughout this document that contain data relative to this subject; i.e., throughout Section 3.7.

There are many instances where a reference is made to sections and, upon finding that section, it in turn references to another section. This situation creates the basis for the next category...........

3. Division and Anonymity of Criteria - These two classifications can best be explained by combining them, because, for all practical purposes, they go hand-in-hand. On the surface, the following comments may seem superficial and a matter of personal preference. However, upon scrutinizing MSFC-STD-512 more closely and attempting to examine it from a user's viewpoint, it seems evident that the data could be restructured in a way that would make the document more organized and easier to use.

In its present format, MSFC-STD-512 contains design criteria relative to the same basic subject in various sections of the document. This leads to a cumbersome search throughout the document in order to assure that all pertinent criteria are being considered for a specific application. This is not meant to imply that this condition exists in all cases, but there are enough instances with this potential to warrant some reorganization. In conjunction with this, there are criteria applicable to specific subjects

which are located under sections that may not immediately appear to be the section in which these requirements would be contained. Ideally, all requirements related to a specific system or hardware item should be included in the same section. The following examples illustrate a few of the reorganizational modifications that would "streamline" the MSFC-STD-512 document.

- Under Atmosphere Ventilation, Section 2.3, there are subparagraphs for Toxic Gas Dissipation, Odor Control, and Particulate Matter Control. There are additional criteria relative to these subjects contained in Section 3.7.4.1 starting on Page 3-168, entitled Odor and Particulate Control. Also, under Section 3.7.6, Microbiological Control, there are subsections relative to Entrapment of Microbiological Contamination (3.7.6.2.c) and Atmosphere (3.7.6.2.3). In Section 6.2, Physiological Limit Values, data is presented on Gaseous Contaminants and Particulate Contaminants. All of this data could be combined into one common and centralized location.

- Section 2.4, Lighting, contains criteria for internal lighting only. Other sections also contain lighting requirements; i.e., Maintenance, Sleep Equipment, Partial Body Cleansing, Documentation Stowage and Display, and under EVA; Contingency Task Lighting, Lighting and Translating Envelope - Lighting. It is entirely feasible to catalog all lighting requirements, both IVA and EVA, into one section.

- The criteria in Section 3.2, Zero-G Flight Hardware Design relative to equipment restraints, restraint techniques, fasteners, movable equipment, launch and

on-orbit stowage, and the stowage criteria in Section 3.4, could be combined and reorganized into one common section.

- The design criteria for Crew Restraints, Section 3.2.3 and those contained in EVA Section 4, as well as the limited criteria in the habitability area regarding food management, sleep compartments, and waste management could be combined under one section and titled in such a way that any user of the document could find the applicable criteria and recommended solutions for any particular situation requiring crew restraints in one location.

- Touch temperatures are presently located annonymously in two areas; EVA (4.1.5) and Safety (6.2.3.3). These should be combined into one section and titled "Touch Temperatures."

- Trash management criteria are scattered throughout the document, specifying requirements for inert trash, biologically active trash, trash collection, trash storage and disposal. Again, various sections of MSFC-STD-512 have to be researched in order to obtain requirements relative to a complete trash management concept. Centralization of this data is highly recommended.

D. Existing Requirements

During the detailed assessment of MSFC-STD-512, annotations of discrepancies in existing requirements were made. Approximately one-fourth of those significant annotations are presented in Appendix III. They are presented section by section; i.e., Lighting, Spacecraft Artchitecture, Zero-G Flight Hardware Design, etc., with appropriate discussion and recommendations.

APPENDIX I

MSFC-STD-512 Section Applicability to Man-System Interactions

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SECTION #	TITLE	EXPERIMENT SETUP - DIRECT	EXPERIMENT START/STOP	MONITORING @ C&D PANEL	EXPERIMENT CONTROL - DIRECT	EXPERIMENT CONTROL - REMOTE	DIRECT EXPERIMENT OBSERVATION	REMOTE EXPERIMENT OBSERVATION	HOUSEKEEPING	MAINTENANCE	CALIBRATE INSTRUMENTATION	DATA REDUCTION/ANALYSIS	REMOTE PALLET OPERATIONS	FREE FLYING TELEOPERATOR OPS	SUBSATELLITE OPERATIONS	GENERAL WORKSTATION CRITERIA	NOT APPLICABLE-PROGRAM REQ.
MSFC-STD-512 DESIGN CRITERIA	MAN-SYSTEM INTERACTION																
1.	INTRODUCTION																●
2.	GENERAL ENVIRONMENT - INTERIOR SPACECRAFT																●
2.1	ATMOSPHERE COMPOSITION & PRESSURE																●
2.1.1	Atmosphere Composition																●
2.1.1.1	Oxygen																●
2.1.1.2	Carbon Dioxide																●
2.1.1.3	Water Vapor																●
2.1.1.4	Nitrogen & Other Diluents																●
2.1.1.5	Contaminants																●
2.1.2	Pressure																●
2.2	ATMOSPHERE TEMPERATURE & HUMIDITY																●
2.2.1	Comfort Zones																●
2.2.2	Limited Tolerance Zones																●
2.2.2.1	High Temperatures																●
2.2.2.2	Low Temperatures																●
2.3	ATMOSPHERE VENTILATION																●
2.3.1	Airflow Limits																●
2.3.2	Secondary Functions																●
2.3.2.1	Toxic Gas Dissipation																●
2.3.2.2	Odor Control																●
2.3.2.3	Particulate Matter Control																●
2.4	LIGHTING																●
2.4.1	Lighting System Requirements	●	●	●	●	●	●	●	●	●	●	●	●	●	●		
2.4.2	Supplementary Illumination	INTRODUCTORY INFORMATION															
2.4.2.1	Portable Lights								●	●							
2.4.2.2	Emergency Lights																●
2.4.2.3	Photography Lighting	●			●		●										
2.4.2.4	Experiment Lighting				●		●										
2.4.2.5	Power Cables	●			●		●	●	●	●							
2.5	ACOUSTICS	INTRODUCTORY INFORMATION															
2.5.1	Design Speech Interference Levels				●		●										
2.5.2	Reverberation Time																●
2.5.3	Sound Generation & Propagation				●		●										

SECTION #	TITLE (MSFC-STD-512 DESIGN CRITERIA / MAN-SYSTEM INTERACTION)	EXPERIMENT SETUP - DIRECT	EXPERIMENT START/STOP	MONITORING @ C&D PANEL	EXPERIMENT CONTROL - DIRECT	EXPERIMENT CONTROL - REMOTE	DIRECT EXPERIMENT OBSERVATION	REMOTE EXPERIMENT OBSERVATION	HOUSEKEEPING	MAINTENANCE	CALIBRATE INSTRUMENTATION	DATA REDUCTION/ANALYSIS	REMOTE PALLET OPERATIONS	FREE FLYING TELEOPERATOR OPS	SUBSATELLITE OPERATIONS	GENERAL WORKSTATION CRITERIA	NOT APPLICABLE-PROGRAM REQ.
2.5.4	Intermittent Sounds				●		●										
3.	SPACECRAFT INTERIOR DESIGN					INTRODUCTORY INFORMATION											
3.1	INTERIOR LAYOUT																●
3.1.1	Spacecraft Architecture	●	●	●	●	●	●	●	●	●	●	●	●	●	●		
3.1.2	Volume Requirements	●			●	●	●	●									
3.2	ZERO G FLIGHT HARDWARE DESIGN					INTRODUCTORY INFORMATION											
3.2.1	On-Orbit Crew Applied Loads	●	●	●	●	●			●	●	●		●	●	●		
3.2.2	Equipment Restraint					INTRODUCTORY INFORMATION											
3.2.2.1	Restraint Techniques	●			●	●		●	●	●	●	●					
3.2.2.2	Hand Operated Fasteners	●			●	●			●	●	●						
3.2.2.3	Tool Operated Fasteners	●			●	●			●	●	●						
3.2.3	Crew Restraints					INTRODUCTORY INFORMATION											
3.2.3.1	Restraint Loads															●	
3.2.3.2	Neutral Body Position			●	●	●		●		●	●		●	●	●		
3.2.3.3	Functional Reach	●	●		●	●			●	●	●		●	●	●		
3.2.3.4	Design Criteria	●	●	●	●	●	●	●	●	●	●	●	●	●	●		
3.2.4	Crew Mobility Aids	●	●	●	●	●	●	●	●	●	●	●	●	●	●		
3.2.4.1	Traffic Patterns	●	●	●	●	●	●	●	●	●	●	●	●	●	●		
3.2.4.2	Mobility Aid Placement	●	●	●	●	●	●	●	●	●	●	●	●	●	●		
3.2.4.3	Design Criteria (Incl. Grip Surfaces, etc.)	●	●	●	●	●	●	●	●	●	●	●	●	●	●		
3.2.5	Movable Equipment	●							●	●							
3.2.5.1	Launch & On-Orbit Stowage (see 3.2.2 & 3.3)	●							●	●							
3.2.5.2	Equipment Transfer	●			●				●	●							
3.2.6	Hatches & Doors					INTRODUCTORY INFORMATION											
3.2.6.1	Pressure Hatches																●
3.2.6.2	Internal Doors																●
3.2.6.3	Emergency Hatches																●
3.2.7	Viewing Windows					INTRODUCTORY INFORMATION											
3.2.7.1	General Requirements					●		●					●	●	●		
3.2.7.2	Glass Characteristics					●		●					●	●	●		
3.2.7.3	Window Shades & Protective Covers					●		●					●	●	●		
3.2.7.4	Venting & Defogging					●		●	●				●	●	●		
3.2.7.5	Maintenance & Cleaning					●		●		●			●	●	●		

MSFC-STD-512 DESIGN CRITERIA / MAN-SYSTEM INTERACTION		EXPERIMENT SETUP - DIRECT	EXPERIMENT START/STOP	MONITORING @ C&D PANEL	EXPERIMENT CONTROL - DIRECT	EXPERIMENT CONTROL - REMOTE	DIRECT EXPERIMENT OBSERVATION	REMOTE EXPERIMENT OBSERVATION	HOUSEKEEPING	MAINTENANCE	CALIBRATE INSTRUMENTATION	DATA REDUCTION/ANALYSIS	REMOTE PALLET OPERATIONS	FREE FLYING TELEOPERATOR OPS	SUBSATELLITE OPERATIONS	GENERAL WORKSTATION CRITERIA	NOT APPLICABLE-PROGRAM REQ.
SECTION #	TITLE																
3.2.8	Area Closures								●								
3.3	SPACECRAFT MAINTENANCE						INTRODUCTORY INFORMATION										
3.3.1	General									●							
3.3.2	Assumptions									●							
3.3.3	On-Orbit Maintenance									●							
3.3.3.1	IVA (Intra-Vehicular Activity) Maintenance									●							
3.3.3.2	EVA (Extra-Vehicular Activity) Maintenance									●							
3.3.4	Tools & Maintenance Workstation	●								●							
3.3.4.1	General	●								●							
3.3.4.2	Tool Complement	●								●							
3.3.4.3	Dedicated Maintenance Workstation									●							
3.3.4.4	Portable Maintenance Workstation									●							
3.4	STOWAGE	●			●				●	●							
3.4.1	General Location/Functional Grouping	●			●				●	●							
3.4.2	Stowage Management/On-Orbit Inventory	●			●				●	●							
3.4.3	Stowage Module Standardization	●			●				●	●							
3.4.4	Design Requirements	●			●				●	●							
3.5	MARKING & LABELS	●	●	●	●	●			●	●	●		●	●	●		
3.5.1	Types of Information	●	●	●	●	●			●	●	●		●	●	●		
3.5.2	Typography, Spacing & Size	●	●	●	●	●			●	●	●		●	●	●		
3.5.3	Marking Location & Orientation	●	●	●	●	●			●	●	●		●	●	●		
3.5.4	Color and Finish	●	●	●	●	●			●	●	●		●	●	●		
3.5.5	Marking Methods	●	●	●	●	●			●	●	●		●	●	●		
3.6	CONTROLS AND DISPLAYS	●	●	●	●	●			●	●	●	●	●	●	●		
3.6.1	Control/Display Integration	●	●	●	●	●			●	●	●	●	●	●	●		
3.6.1.1	Position Relationships	●	●	●	●	●			●	●	●	●	●	●	●		
3.6.1.2	Movement Relationships	●	●	●	●	●			●	●	●	●	●	●	●		
3.6.2	Visual Displays	●	●	●	●	●			●	●	●	●	●	●	●		
3.6.2.1	Illuminated Displays	●	●	●	●	●			●	●	●	●	●	●	●		
3.6.2.2	Scale Indicators	●	●	●	●	●			●	●	●	●	●	●	●		
3.6.2.3	Cathode Ray Tube (CRT) Displays	●	●	●	●	●			●	●	●	●	●	●	●		
3.6.2.4	Large Scale Displays	●	●	●	●	●			●	●	●	●	●	●	●		
3.6.2.5	Other Displays	●	●	●	●	●			●	●	●	●	●	●	●		
3.6.3	Audio Displays	●	●	●	●	●			●	●	●	●	●	●	●		

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SECTION #	TITLE	EXPERIMENT SETUP - DIRECT	EXPERIMENT START/STOP	MONITORING @ C&D PANEL	EXPERIMENT CONTROL - DIRECT	EXPERIMENT CONTROL - REMOTE	DIRECT EXPERIMENT OBSERVATION	REMOTE EXPERIMENT OBSERVATION	HOUSEKEEPING	MAINTENANCE	CALIBRATE INSTRUMENTATION	DATA REDUCTION/ANALYSIS	REMOTE PALLET OPERATIONS	FREE FLYING TELEOPERATOR OPS	SUBSATELLITE OPERATIONS	GENERAL WORKSTATION CRITERIA	NOT APPLICABLE-PROGRAM REQ.
(MSFC-STD-512 DESIGN CRITERIA / MAN-SYSTEM INTERACTION)																	
3.6.4	Controls	●	●	●	●	●			●	●	●	●	●	●	●		
3.6.4.1	General Criteria	●	●	●	●	●			●	●	●	●	●	●	●		
3.6.4.2	Rotary Controls	●	●	●	●	●			●	●	●	●	●	●	●		
3.6.4.3	Linear Controls	●	●	●	●	●			●	●	●	●	●	●	●		
3.6.4.4	High Force Controls	●	●	●	●	●			●	●	●	●	●	●	●		
3.7	HABITABILITY								INTRODUCTORY INFORMATION								
3.7.1	Sleep Equipment																●
3.7.1.1	Restraints																●
3.7.1.2	Environment																●
3.7.1.3	Auxiliary Equipment																●
3.7.2	Food Management																●
3.7.2.1	Equipment Arrangement																●
3.7.2.2	Food Stowage & Resupply																●
3.7.2.3	Food Preparation & Consumption Equipment																●
3.7.2.4	Food Trash Management																●
3.7.3	Potable Water																●
3.7.3.1	Storage																●
3.7.3.2	Treatment & Conditioning																●
3.7.3.3	Water Distribution, Dispensing & Disposal																●
3.7.4	Waste Management																●
3.7.4.1	Body Wastes																●
3.7.4.2	Trash Management	●			●				●	●		●					
3.7.5	Hygiene								INTRODUCTORY INFORMATION								
3.7.5.1	Partial Body Cleaning				●				●	●							
3.7.5.2	Whole Body Cleaning																●
3.7.5.3	Grooming																●
3.7.5.4	Dental Health																●
3.7.6	Microbiological Control								INTRODUCTORY INFORMATION								
3.7.6.1	General Requirements	●			●				●	●							
3.7.6.2	Control Approaches & Equipment	●			●				●	●							
3.7.7	Crew Accessories								INTRODUCTORY INFORMATION								
3.7.7.1	Entertainment Provisions																●
3.7.7.2	Personal Stowage Provisions																●

MSFC-STD-512 DESIGN CRITERIA / MAN-SYSTEM INTERACTION		EXPERIMENT SETUP - DIRECT	EXPERIMENT START/STOP	MONITORING @ C&D PANEL	EXPERIMENT CONTROL - DIRECT	EXPERIMENT CONTROL - REMOTE	DIRECT EXPERIMENT OBSERVATION	REMOTE EXPERIMENT OBSERVATION	HOUSEKEEPING	MAINTENANCE	CALIBRATE INSTRUMENTATION	DATA REDUCTION/ANALYSIS	REMOTE PALLET OPERATIONS	FREE FLYING TELEOPERATOR OPS	SUBSATELLITE OPERATIONS	GENERAL WORKSTATION CRITERIA	NOT APPLICABLE-PROGRAM REQ.
SECTION #	TITLE																
3.7.7.3	Operational Crew Accessories	●		●	●	●	●	●	●	●	●	●	●	●	●		
3.7.8	Colors & Finishes															●	
3.7.8.1	Habitation Areas															●	
3.7.8.2	Equipment															●	
3.7.8.3	Color Coding	●	●	●	●	●			●	●	●	●	●	●	●		
3.7.9	Housekeeping								●								
3.8	MISSION OPERATIONS EQUIPMENT	●	●		●	●			●	●	●	●	●	●	●		
3.8.1	General Requirements	●	●		●	●			●	●	●	●	●	●	●		
3.8.2	Documentation Stowage & Display	●	●		●	●			●	●	●	●	●	●	●		
3.8.3	Documentation Update & Recording	●	●		●	●			●	●	●	●	●	●	●		
4.	EXTRAVEHICULAR ACTIVITY (EVA)						INTRODUCTORY INFORMATION										
4.1	GENERAL CONSIDERATIONS									●							
4.1.1	EVA Duration									●							
4.1.2	EVA Workloads									●							
4.1.3	Anthropometry (suited)									●							
4.1.3.1	Manual Dexterity									●							
4.1.3.2	Reach Envelope									●							
4.1.3.3	Visual Restrictions									●							
4.1.4	Strength Capabilities									●							
4.1.5	Touch Temperature									●							
4.1.6	Umbilical Management									●							
4.1.7	Safety									●							
4.1.7.1	Sharp Edges & Corners									●							
4.1.7.2	Entanglement									●							
4.1.8	Contingency Tasks									●							
4.1.8.1	Accessibility									●							
4.1.8.2	Crew Translation									●							
4.1.8.3	Crew Restraint									●							
4.1.8.4	Contingency Task Lighting									●							
4.2	WORKSTATION DESIGN									●							
4.2.1	Crew Restraints									●							
4.2.1.1	Foot Restraints									●							
4.2.1.2	Handrails/Handholds									●							

SECTION # (MSFC-STD-512 DESIGN CRITERIA)	TITLE (MAN-SYSTEM INTERACTION)	EXPERIMENT SETUP - DIRECT	EXPERIMENT START/STOP	MONITORING @ C&D PANEL	EXPERIMENT CONTROL - DIRECT	EXPERIMENT CONTROL - REMOTE	DIRECT EXPERIMENT OBSERVATION	REMOTE EXPERIMENT OBSERVATION	HOUSEKEEPING	MAINTENANCE	CALIBRATE INSTRUMENTATION	DATA REDUCTION/ANALYSIS	REMOTE PALLET OPERATIONS	FREE FLYING TELEOPERATOR OPS	SUBSATELLITE OPERATIONS	GENERAL WORKSTATION CRITERIA	NOT APPLICABLE-PROGRAM REQ.
4.2.1.3	Tethers									●							
4.2.2	Hardware Removal/Installation Interface									●							
4.2.2.1	Visual Aligument									●							
4.2.2.2	Tactile Alignment									●							
4.2.2.3	Removal/Installation Force									●							
4.2.2.4	Use of Detents & Overcenter Devices									●							
4.2.2.5	Visual Indicators									●							
4.2.2.6	Fasteners									●							
4.2.3	Temporary Hardware Restraints									●							
4.2.4	Cargo Transfer									●							
4.2.4.1	Mechanical									●							
4.2.4.2	Manual Aided									●							
4.2.4.3	Manual									●							
4.2.5	Accessibility									●							
4.2.5.1	Work Envelope									●							
4.2.5.2	Tool/Equipment Maneuvering Space									●							
4.2.6	Visual Aids									●							
4.2.6.1	Labels/Checklists									●							
4.2.6.2	Nomenclature									●							
4.2.6.3	Color Coding									●							
4.2.6.4	Controls/Displays									●							
4.2.7	Lighting									●							
4.2.8	Colors									●							
4.3	TOOL USAGE/TOOLS									●							
4.4	TRANSLATION ROUTE DESIGN									●							
4.4.1	Crew Translation/Restraint									●							
4.4.1.1	Handrails/Handholds									●							
4.4.1.2	Translation Envelope									●							
4.4.2	Lighting									●							
4.4.3	Colors									●							
4.4.4	Adjacent Equipment Guarding									●							
5.	ANTHROPOMETRY & CREW CAPABILITY						INTRODUCTORY INFORMATION										
5.1	ANTHROPOMETRY															●	

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MAN-SYSTEM INTERACTION / MSFC-STD-512 DESIGN CRITERIA

SECTION #	TITLE	EXPERIMENT SETUP - DIRECT	EXPERIMENT START/STOP	MONITORING @ C&D PANEL	EXPERIMENT CONTROL - DIRECT	EXPERIMENT CONTROL - REMOTE	DIRECT EXPERIMENT OBSERVATION	REMOTE EXPERIMENT OBSERVATION	HOUSEKEEPING	MAINTENANCE	CALIBRATE INSTRUMENTATION	DATA REDUCTION/ANALYSIS	REMOTE PALLET OPERATIONS	FREE FLYING TELEOPERATOR OPS	SUBSATELLITE OPERATIONS	GENERAL WORKSTATION CRITERIA	NOT APPLICABLE-PROGRAM REQ.
5.1.1	General															●	
5.1.2	Astronaut Population															●	
5.1.2.1	Clothing & Equipment															●	
5.2	CREW CAPABILITIES															●	
5.2.1	General															●	
5.2.2	Strength Capabilities (Male-Female)															●	
5.2.3	Strength Measurements															●	
5.2.4	Body Motion															●	
5.2.5	Reach Envelopes															●	
6.	CREW SAFETY						INTRODUCTORY INFORMATION										
6.1	ELECTRICAL SYSTEMS															●	
6.1.1	Equipment Design															●	
6.1.2	Crew Operated Connectors, Switches & Circuit Breakers															●	
6.2	PHYSIOLOGICAL LIMIT VALUES															●	
6.2.1	Gaseous Contaminants															●	
6.2.2	Particulate Contaminants															●	
6.2.3	Radiation															●	
6.2.3.1	Non-Ionizing Radiation															●	
6.2.3.2	Ionizing Radiation															●	
6.2.4	Surface Touch Temperature Limits															●	
6.3	FIRE PROTECTION AND CONTROL																●
6.3.1	Sensing Techniques & Parameters																●
6.3.1.1	Radiation Detection																●
6.3.1.2	Smoke Sensors																●
6.3.2	Caution & Warning Equipment																●
6.3.3	Fire Extinguishing																●
6.4	LEAK DETECTION & CONTROL																●
6.4.1	Sensing																●
6.4.1.1	Overall Sensing																●
6.4.1.2	Leak Localization																●
6.4.1.3	Caution & Warning Provisions																●
6.4.2	Repair																●

SECTION #	TITLE	EXPERIMENT SETUP - DIRECT	EXPERIMENT START/STOP	MONITORING @ C&D PANEL	EXPERIMENT CONTROL - DIRECT	EXPERIMENT CONTROL - REMOTE	DIRECT EXPERIMENT OBSERVATION	REMOTE EXPERIMENT OBSERVATION	HOUSEKEEPING	MAINTENANCE	CALIBRATE INSTRUMENTATION	DATA REDUCTION/ANALYSIS	REMOTE PALLET OPERATIONS	FREE FLYING TELEOPERATOR OPS	SUBSATELLITE OPERATIONS	GENERAL WORKSTATION CRITERIA	NOT APPLICABLE-PROGRAM REQ.
6.5	CAUTION AND WARNING SYSTEMS																●
6.5.1	Fire																●
6.5.2	Pressure																●
6.5.3	Partial Pressure																●
6.5.4	Toxic Gas																●
6.5.5	Electrical																●
6.6	EMERGENCY EQUIPMENT																●
6.6.1	Emergency Breathing																●
6.6.1.1	Location																●
6.6.1.2	Accessibility & Stowage																●
6.6.2	Escape Techniques & Provisions																●
6.7	ORDNANCE SYSTEMS												●				
6.7.1	Unexploded Ordnance												●				
6.7.2	Arming/Disarming Devices												●				
6.7.3	Explosion Protection												●				
6.8	CORNERS, EDGES & OTHER HAZARDS															●	
6.8.1	Exposed Edges															●	
6.8.2	Exposed Corners															●	
6.8.3	Exposed Protrusions															●	
6.8.4	Pinching, Snagging & Cutting															●	
6.8.5	Mechanical Stored Energy Devices															●	
7.	ZERO GRAVITY SIMULATION																●
7.1	SIMULATION MODES																●
7.1.1	Comparison of Modes, Advantages & Disadv.																●
7.1.1.1	One-G Simulations																●
7.1.1.2	Zero Gravity Flight																●
7.1.1.3	Neutral Buoyancy																●
7.1.1.4	Multiple-Degrees-of-Freedom																●
7.1.2	Specific Mode Applications																●
7.2	MOCKUPS																●
7.2.1	Level of Fidelity																●
7.2.2	Design Criteria																●

MSFC-STD-512 DESIGN CRITERIA / MAN-SYSTEM INTERACTION

APPENDIX II

MSFC-STD-512 Section Applicability to Scientific Disciplines

SECTION #	TITLE	ASTRONOMY (AS)	HIGH ENERGY ASTROPHYSICS (HE)	SOLAR PHYSICS (SO)	ATMOS. & SPACE PHYSICS (AP)	EARTH OBSERVATION (EO)	SPACE PROCESSING APPL. (SP)	EARTH & OCEAN PHYSICS (OP)	LIFE SCIENCES (LS)	SPACE TECHNOLOGY (ST)	COMM. & NAVIGATION (CN)	GENERAL WORKSTATION CRITERIA	NOT APPLICABLE - PROGRAM REQ.
	MSFC-STD-512 DESIGN CRITERIA / PAYLOAD SCIENTIFIC DISCIPLINE												
1.	INTRODUCTION												●
2.	GENERAL ENVIRONMENT - INTERIOR SPACECRAFT												●
2.1	ATMOSPHERE COMPOSITION & PRESSURE												●
2.1.1	Atmosphere Composition												●
2.1.1.1	Oxygen												●
2.1.1.2	Carbon Dioxide												●
2.1.1.3	Water Vapor												●
2.1.1.4	Nitrogen & Other Diluents												●
2.1.1.5	Contaminants												●
2.1.2	Pressure												●
2.2	ATMOSPHERE TEMPERATURE & HUMIDITY												●
2.2.1	Comfort Zones												●
2.2.2	Limited Tolerance Zones												●
2.2.2.1	High Temperatures												●
2.2.2.2	Low Temperatures												●
2.3	ATMOSPHERE VENTILATION												●
2.3.1	Airflow Limits												●
2.3.2	Secondary Functions												●
2.3.2.1	Toxic Gas Dissipation												●
2.3.2.2	Odor Control												●
2.3.2.3	Particulate Matter Control												●
2.4	LIGHTING												●
2.4.1	Lighting System Requirements	●	●	●	●	●	●	●	●	●	●		
2.4.2	Supplementary Illumination	INTRODUCTORY INFORMATION											
2.4.2.1	Portable Lights	●	●	●		●	●	●	●	●	●		
2.4.2.2	Emergency Lights												●
2.4.2.3	Photography Lighting	●	●			●	●	●	●	●	●		
2.4.2.4	Experiment Lighting	●	●			●	●	●	●	●	●		
2.4.2.5	Power Cables	●	●	●	●	●	●	●	●	●	●		
2.5	ACOUSTICS	INTRODUCTORY INFORMATION											
2.5.1	Design Speech Interference Levels	●	●			●	●	●	●	●	●		
2.5.2	Reverberation Time												●
2.5.3	Sound Generation & Propagation	●	●			●	●	●	●	●	●		

MSFC-STD-512 DESIGN CRITERIA / PAYLOAD SCIENTIFIC DISCIPLINE		ASTRONOMY (AS)	HIGH ENERGY ASTROPHYSICS (HE)	SOLAR PHYSICS (SO)	ATMOS. & SPACE PHYSICS (AP)	EARTH OBSERVATION (EO)	SPACE PROCESSING APPL. (SP)	EARTH & OCEAN PHYSICS (OP)	LIFE SCIENCES (LS)	SPACE TECHNOLOGY (ST)	COMM. & NAVIGATION (CN)	GENERAL WORKSTATION CRITERIA	NOT APPLICABLE - PROGRAM REQ
SECTION #	TITLE												
2.5.4	Intermittent Sounds	●	●			●	●	●	●	●	●		
3.	SPACECRAFT INTERIOR DESIGN	INTRODUCTORY INFORMATION											
3.1	INTERIOR LAYOUT												●
3.1.1	Spacecraft Architecture	●	●	●	●	●	●	●	●	●	●		
3.1.2	Volume Requirements	●	●	●	●	●	●	●	●	●	●		
3.2	ZERO G FLIGHT HARDWARE DESIGN	INTRODUCTORY INFORMATION											
3.2.1	On-Orbit Crew Applied Loads	●	●	●	●	●	●	●	●	●	●		
3.2.2	Equipment Restraint	INTRODUCTORY INFORMATION											
3.2.2.1	Restraint Techniques	●	●	●	●	●	●	●	●	●	●		
3.2.2.2	Hand Operated Fasteners	●	●	●	●	●	●	●	●	●	●		
3.2.2.3	Tool Operated Fasteners	●	●	●	●	●	●	●	●	●	●		
3.2.3	Crew Restraints	INTRODUCTORY INFORMATION											
3.2.3.1	Restraint Loads											●	
3.2.3.2	Neutral Body Position	●	●	●	●	●	●	●	●	●	●		
3.2.3.3	Functional Reach	●	●	●	●	●	●	●	●	●	●		
3.2.3.4	Design Criteria	●	●	●	●	●	●	●	●	●	●		
3.2.4	Crew Mobility Aids	●	●	●	●	●	●	●	●	●	●		
3.2.4.1	Traffic Patterns	●	●	●	●	●	●	●	●	●	●		
3.2.4.2	Mobility Aid Placement	●	●	●	●	●	●	●	●	●	●		
3.2.4.3	Design Criteria (Incl. Grip Surfaces, etc)	●	●	●	●	●	●	●	●	●	●		
3.2.5	Movable Equipment	●	●	●		●	●	●	●	●	●		
3.2.5.1	Launch & On-Orbit Stowage (see 3.2.2 & 3.3)	●	●	●		●	●	●	●	●	●		
3.2.5.2	Equipment Transfer	●	●	●		●	●	●	●	●	●		
3.2.6	Hatches & Doors	INTRODUCTORY INFORMATION											
3.2.6.1	Pressure Hatches												●
3.2.6.2	Internal Doors												●
3.2.6.3	Emergency Hatches												●
3.2.7	Viewing Windows	INTRODUCTORY INFORMATION											
3.2.7.1	General Requirements	●	●	●	●	●	●	●	●	●	●		
3.2.7.2	Glass Characteristics	●	●	●	●	●	●	●	●	●	●		
3.2.7.3	Window Shades & Protective Covers	●	●	●	●	●	●	●	●	●	●		
3.2.7.4	Venting & Defogging	●	●	●	●	●	●	●	●	●	●		
3.2.7.5	Maintenance & Cleaning	●	●	●	●	●	●	●	●	●	●		

MSFC-STD-512 DESIGN CRITERIA / PAYLOAD SCIENTIFIC DISCIPLINE		ASTRONOMY (AS)	HIGH ENERGY ASTROPHYSICS (HE)	SOLAR PHYSICS (SO)	ATMOS. & SPACE PHYSICS (AP)	EARTH OBSERVATION (EO)	SPACE PROCESSING APPL. (SP)	EARTH & OCEAN PHYSICS (OP)	LIFE SCIENCES (LS)	SPACE TECHNOLOGY (ST)	COMM. & NAVIGATION (CN)	GENERAL WORKSTATION CRITERIA	NOT APPLICABLE - PROGRAM REQ.
SECTION #	TITLE												
3.2.8	Area Closures	●		●		●	●	●	●	●	●		
3.3	SPACECRAFT MAINTENANCE				INTRODUCTORY INFORMATION								
3.3.1	General	●	●			●			●				
3.3.2	Assumptions	●	●			●			●				
3.3.3	On-Orbit Maintenance	●	●			●			●				
3.3.3.1	IVA (Intra-Vehicular Activity) Maintenance	●	●			●			●				
3.3.3.2	EVA (Extra-Vehicular Activity) Maintenance	●	●			●			●				
3.3.4	Tools & Maintenance Workstation	●				●	●	●	●	●	●		
3.3.4.1	General	●				●	●	●	●	●	●		
3.3.4.2	Tool Complement	●				●	●	●	●	●	●		
3.3.4.3	Dedicated Maintenance Workstation	●	●			●			●				
3.3.4.4	Portable Maintenance Workstation	●	●			●			●				
3.4	STOWAGE	●	●	●		●	●	●	●	●	●		
3.4.1	General Location/Functional Grouping	●	●	●		●	●	●	●	●	●		
3.4.2	Stowage Management/On-Orbit Inventory	●	●	●		●	●	●	●	●	●		
3.4.3	Stowage Module Standardization	●	●	●		●	●	●	●	●	●		
3.4.4	Design Requirements	●	●	●		●	●	●	●	●	●		
3.5	MARKINGS & LABELS	●	●	●	●	●	●	●	●	●	●		
3.5.1	Types of Information	●	●	●	●	●	●	●	●	●	●		
3.5.2	Typography, Spacing & Size	●	●	●	●	●	●	●	●	●	●		
3.5.3	Marking Location & Orientation	●	●	●	●	●	●	●	●	●	●		
3.5.4	Color and Finish	●	●	●	●	●	●	●	●	●	●		
3.5.5	Marking Methods	●	●	●	●	●	●	●	●	●	●		
3.6	CONTROLS AND DISPLAYS	●	●	●	●	●	●	●	●	●	●		
3.6.1	Control/Display Integration	●	●	●	●	●	●	●	●	●	●		
3.6.1.1	Position Relationships	●	●	●	●	●	●	●	●	●	●		
3.6.1.2	Movement Relationships	●	●	●	●	●	●	●	●	●	●		
3.6.2	Visual Displays	●	●	●	●	●	●	●	●	●	●		
3.6.2.1	Illuminated Displays	●	●	●	●	●	●	●	●	●	●		
3.6.2.2	Scale Indicators	●	●	●	●	●	●	●	●	●	●		
3.6.2.3	Cathode Ray Tube (CRT) Displays	●	●	●	●	●	●	●	●	●	●		
3.6.2.4	Large Scale Displays	●	●	●	●	●	●	●	●	●	●		
3.6.2.5	Other Displays	●	●	●	●	●	●	●	●	●	●		

SECTION #	TITLE	ASTRONOMY (AS)	HIGH ENERGY ASTROPHYSIC (HE)	SOLAR PHYSIC (SO)	ATMOS. & SPACE PHYSICS (AP)	EARTH OBSERVATION (EO)	SPACE PROCESSING APPL. (SP)	EARTH & OCEAN PHYSICS (OP)	LIFE SCIENCES (LS)	SPACE TECHNOLOGY (ST)	COMM. & NAVIGATION (CN)	GENERAL WORKSTATION CRITERIA	NOT APPLICABLE - PROGRAM REQ.
MSFC -STD-512 DESIGN CRITERIA / PAYLOAD SCIENTIFIC DISCIPLINE													
3.6.3	Audio Displays	●	●	●	●	●	●	●	●	●	●		
3.6.4	Controls	●	●	●	●	●	●	●	●	●	●		
3.6.4.1	General Criteria	●	●	●	●	●	●	●	●	●	●		
3.6.4.2	Rotary Controls	●	●	●	●	●	●	●	●	●	●		
3.6.4.3	Linear Controls	●	●	●	●	●	●	●	●	●	●		
3.6.4.4	High Force Controls	●	●	●	●	●	●	●	●	●	●		
3.7	HABITABILITY					INTRODUCTORY INFORMATION							
3.7.1	Sleep Equipment												●
3.7.1.1	Restraints												●
3.7.1.2	Environment												●
3.7.1.3	Auxiliary Equipment												●
3.7.2	Food Management												●
3.7.2.1	Equipment Arrangement												●
3.7.2.2	Food Stowage & Resupply												●
3.7.2.3	Food Preparation & Consumption Equipment												●
3.7.2.4	Food Trash Management												●
3.7.3	Potable Water												●
3.7.3.1	Storage												●
3.7.3.2	Treatment & Conditioning												●
3.7.3.3	Water Distribution, Dispensing & Disposal												●
3.7.4	Waste Management												●
3.7.4.1	Body Wastes												●
3.7.4.2	Trash Management	●	●	●	●	●	●	●	●	●	●		
3.7.5	Hygiene					INTRODUCTORY INFORMATION							
3.7.5.1	Partial Body Cleaning	●	●	●		●	●	●	●	●	●		
3.7.5.2	Whole Body Cleaning												●
3.7.5.3	Grooming												●
3.7.5.4	Dental Health												●
3.7.6	Microbiological Control					INTRODUCTORY INFORMATION							
3.7.6.1	General Requirements	●	●	●		●	●	●	●	●	●		
3.7.6.2	Control Approaches & Equipment	●	●	●		●	●	●	●	●	●		
3.7.7	Crew Accessories					INTRODUCTORY INFORMATION							
3.7.7.1	Entertainment Provisions												●

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MSFC-STD-512 DESIGN CRITERIA / PAYLOAD SCIENTIFIC DISCIPLINE		ASTRONOMY (AS)	HIGH ENERGY ASTROPHYSICS (HE)	SOLAR PHYSICS (SO)	ATMOS. & SPACE PHYSICS (AP)	EARTH OBSERVATION (EO)	SPACE PROCESSING APPL. (SP)	EARTH & OCEAN PHYSICS (OP)	LIFE SCIENCES (LS)	SPACE TECHNOLOGY (ST)	COMM. & NAVIGATION (CN)	GENERAL WORKSTATION CRITERIA	NOT APPLICABLE - PROGRAM REQ.
SECTION #	TITLE												
3.7.7.2	Personal Stowage Provisions												●
3.7.7.3	Operational Crew Accessories	●	●	●	●	●	●	●	●	●	●		
3.7.8	Colors & Finishes											●	
3.7.8.1	Habitation Areas											●	
3.7.8.2	Equipment											●	
3.7.8.3	Color Coding	●	●	●	●	●	●	●	●	●	●		
3.7.9	Housekeeping	●		●		●	●	●	●	●	●		
3.8	MISSION OPERATIONS EQUIPMENT	●	●	●	●	●	●	●	●	●	●		
3.8.1	General Requirements	●	●	●	●	●	●	●	●	●	●		
3.8.2	Documentation Stowage & Display	●	●	●	●	●	●	●	●	●	●		
3.8.3	Documentation Update & Recording	●	●	●	●	●	●	●	●	●	●		
4.	EXTRAVEHICULAR ACTIVITY (EVA)				INTRODUCTORY INFORMATION								
4.1	GENERAL CONSIDERATIONS	●	●			●			●				
4.1.1	EVA Duration	●	●			●			●				
4.1.2	EVA Workloads	●	●			●			●				
4.1.3	Anthropometry (suited)	●	●			●			●				
4.1.3.1	Manual Dexterity	●	●			●			●				
4.1.3.2	Reach Envelope	●	●			●			●				
4.1.3.3	Visual Restrictions	●	●			●			●				
4.1.4	Strength Capabilities	●	●			●			●				
4.1.5	Touch Temperature	●	●			●			●				
4.1.6	Umbilical Management	●	●			●			●				
4.1.7	Safety	●	●			●			●				
4.1.7.1	Sharp Edges & Corners	●	●			●			●				
4.1.7.2	Entanglement	●	●			●			●				
4.1.8	Contingency Tasks	●	●			●			●				
4.1.8.1	Accessibility	●	●			●			●				
4.1.8.2	Crew Translation	●	●			●			●				
4.1.8.3	Crew Restraint	●	●			●			●				
4.1.8.4	Contingency Task Lighting	●	●			●			●				
4.2	WORKSTATION DESIGN	●	●			●			●				
4.2.1	Crew Restraints	●	●			●			●				
4.2.1.1	Foot Restraints	●				●			●				

SECTION #	TITLE	ASTRONOMY (AS)	HIGH ENERGY ASTROPHYSICS(HE)	SOLAR PHYSICS (SO)	ATMOS. & SPACE PHYSICS (AP)	EARTH OBSERVATION (EO)	SPACE PROCESSING APPL. (SP)	EARTH & OCEAN PHYSICS (OP)	LIFE SCIENCES (LS)	SPACE TECHNOLOGY (ST)	COMM. & NAVIGATION (CN)	GENERAL WORKSTATION CRITERIA	NOT APPLICABLE - PROGRAM REQ.
MSFC-STD-512 DESIGN CRITERIA	PAYLOAD SCIENTIFIC DISCIPLINE												
5.1	ANTHROPOMETRY											●	
5.1.1	General											●	
5.1.2	Astronaut Population											●	
5.1.2.1	Clothing & Equipment											●	
5.2	CREW CAPABILITIES											●	
5.2.1	General											●	
5.2.2	Strength Capabilities (Male - Female)											●	
5.2.3	Strength Measurements											●	
5.2.4	Body Motion											●	
5.2.5	Reach Envelopes											●	
6.	CREW SAFETY					INTRODUCTORY INFORMATION							
6.1	ELECTRICAL SYSTEMS											●	
6.1.1	Equipment Design											●	
6.1.2	Crew Operated Connectors, Switches &												
	Circuit Breakers											●	
6.2	PHYSIOLOGICAL LIMIT VALUES											●	
6.2.1	Gaseous Contaminants											●	
6.2.2	Particulate Contaminants											●	
6.2.3	Radiation											●	
6.2.3.1	Non Ionizing Radiation											●	
6.2.3.2	Ionizing Radiation											●	
6.2.4	Surface Touch Temperature Limits											●	
6.3	FIRE PROTECTION AND CONTROL											●	
6.3.1	Sensing Techniques & Parameters												●
6.3.1.1	Radiation Detection												●
6.3.1.2	Smoke Sensors												●
6.3.2	Caution & Warning Equipment												●
6.3.3	Fire Extinguishing												●
6.4	LEAK DETECTION AND CONTROL												●
6.4.1	Sensing												●
6.4.1.1	Overall Sensing												●
6.4.1.2	Leak Localization												●
6.4.1.3	Caution & Warning Provisions												●

SECTION #	TITLE — MSFC-STD-512 DESIGN CRITERIA / PAYLOAD SCIENTIFIC DISCIPLINE	ASTRONOMY (AS)	HIGH ENERGY ASTROPHYSICS (HE)	SOLAR PHYSICS (SO)	ATMOS. & SPACE PHYSICS (AP)	EARTH OBSERVATION (EO)	SPACE PROCESSING APPL. (SP)	EARTH & OCEAN PHYSICS (OP)	LIFE SCIENCES (LS)	SPACE TECHNOLOGY (ST)	COMM. & NAVIGATION (CN)	GENERAL WORKSTATION CRITERIA	NOT APPLICABLE - PROGRAM REQ.
4.2.1.2	Handrails/Handholds	●	●			●			●				
4.2.1.3	Tethers	●	●			●			●				
4.2.2	Hardware Removal/Installation Interface	●	●			●			●				
4.2.2.1	Visual Alignment	●	●			●			●				
4.2.2.2	Tactile Alignment	●	●			●			●				
4.2.2.3	Removal/Installation Force	●	●			●			●				
4.2.2.4	Use of Detents & Overcenter Devices	●	●			●			●				
4.2.2.5	Visual Indicators	●	●			●			●				
4.2.2.6	Fasteners	●	●			●			●				
4.2.3	Temporaty Hardware Restraints	●	●			●			●				
4.2.4	Cargo Transfer	●	●			●			●				
4.2.4.1	Mechanical	●	●			●			●				
4.2.4.2	Manual Aided	●	●			●			●				
4.2.4.3	Manual	●	●			●			●				
4.2.5	Accessability	●	●			●			●				
4.2.5.1	Work Envelope	●	●			●			●				
4.2.5.2	Tool/Equipment Maneuvering Space	●	●			●			●				
4.2.6	Visual Aids	●	●			●			●				
4.2.6.1	Labels/Checklists	●	●			●			●				
4.2.6.2	Nomenclatures	●	●			●			●				
4.2.6.3	Color Coding	●	●			●			●				
4.2.6.4	Controls/Displays	●	●			●			●				
4.2.7	Lighting	●	●			●			●				
4.2.8	Colors	●	●			●			●				
4.3	TOOL USEAGE/TOOLS	●	●			●			●				
4.4	TRANSLATION ROUTE DESIGN	●	●			●			●				
4.4.1	Crew Translation/Restraint	●	●			●			●				
4.4.1.1	Handrails/Handholds	●	●			●			●				
4.4.1.2	Translation Envelope	●	●			●			●				
4.4.2	Lighting	●	●			●			●				
4.4.3	Colors	●	●			●			●				
4.4.4	Adjacent Equipment Guarding	●	●			●			●				
5.	ANTHROPOMETRY & CREW CAPABILITY					INTRODUCTORY INFORMATION							

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MSFC-STD-512 DESIGN CRITERIA / PAYLOAD SCIENTIFIC DISCIPLINE

SECTION #	TITLE	ASTRONOMY (AS)	HIGH ENERGY ASTROPHYSICS(HE)	SOLAR PHYSICS (SO)	ATMOS. & SPACE PHYSICS (AP)	EARTH OBSERVATION (EO)	SPACE PROCESSING APPL. (SP)	EARTH & OCEAN PHYSICS (OP)	LIFE SCIENCES (LS)	SPACE TECHNOLOGY (ST)	COMM. & NAVIGATION (CN)	GENERAL WORKSTATION CRITERIA	NOT APPLICABLE - PROGRAM REQ.
6.4.2	Repair												●
6.5	CAUTION AND WARNING SYSTEMS												●
6.5.1	Fire												●
6.5.2	Pressure												●
6.5.3	Partial Pressure												●
6.5.4	Toxic Gas												●
6.5.5	Electrical												●
6.6	EMERGENCY EQUIPMENT												●
6.6.1	Emergency Breathing												●
6.6.1.1	Location												●
6.6.1.2	Accessability & Stowage												●
6.6.2	Escape Techniques & Provisions												●
6.7	ORDNANCE SYSTEMS	●	●	●	●	●		●	●	●	●		
6.7.1	Unexploded Ordnance	●	●	●	●	●		●	●	●	●		
6.7.2	Arming/Disarming Devices	●	●	●	●	●		●	●	●	●		
6.7.3	Explosion Protection	●	●	●	●	●		●	●	●	●		
6.8	CORNERS, EDGES & OTHER HAZARDS											●	
6.8.1	Exposed Edges											●	
6.8.2	Exposed Corners											●	
6.8.3	Exposed Protrusions											●	
6.8.4	Pinching, Snagging & Cutting											●	
6.8.5	Mechanical Stored Energy Devices											●	
7.	ZERO GRAVITY SIMULATION												●
7.1	SIMULATION MODES												●
7.1.1	Comparison of Modes, Advantages & Disadvan.												●
7.1.1.1	One-G Simulation												●
7.1.1.2	Zero Gravity Flight												●
7.1.1.3	Neutral Buoyancy												●
7.1.1.4	Multiple-Degrees-of-Freedom												●
7.1.2	Specific Mode Applications												●
7.2	MOCKUPS											●	
7.2.1	Level of Fidelity											●	
7.2.2	Design Criteria											●	

APPENDIX III

Significant Annotations

SECTION/PAGE	EXISTING CRITERIA	DISCUSSION/RECOMMENDATION
	SPACECRAFT ARCHITECTURE	
This section, probably more than any other section in MSFC-STD-512, could be the most contrary simply because, as stated in the introductory paragraph, the design requirements contained in this section are applicable for 30 through 90-day missions. This does not mean the requirements are not valid, but only there will have to be some modifications/concessions in light of the short duration missions and available space on Orbiter for habitation, etc.		
3.1.1 (pg. 3-1)	Activity areas that have incompatible requirements and characteristics, i.e., sleep areas (sound isolation) and waste management (noisy blowers and separators) shall be separated to minimize weight penalties for acoustical treatment.	The Skylab sleep and waste management compartments were separated by a common wall (which fulfills the intent of this requirement as presently written) -- which proved to be unsatisfactory for sound isolation. This was especially true when sleeping crewmen were awakened if the fecal/urine collector was used by another crewman. It may have been more desirable if separation were accomplished by another compartment--not just a common wall. Rewrite, perhaps as follows: Activity areas having incompatible (sound isolation) and waste management (noisy blowers and separators) shall be separated by another compartment, if possible, to minimize weight penalties for acoustical treatment. The use of a common wall as an acoustical barrier shall be avoided if at all possible.
3.1.1 (pg. 3.2)	All workstations shall conform to a basic common design with modifications only as required to accommodate the unique requirements of that workstation.	If there is an established workstation common design, it should be illustrated in the "Example" column. More specifics should be provided for this requirement or else it should be deleted from MSFC-STD-512.
3.1.1 (pg. 3.2)	Functional group interrelation shall be a prime consideration in the basic physical arrangement. All equipment within a compartment or area shall be compatible in the following: - Timeline - Environment Noise/Vibration, Air Flow Contamination, Temperature Odor Light	The meaning of this requirement is difficult to interpret. It would appear that this is a combination of functional and operational characteristics, the meaning of which has not been properly expressed. The real intent of this requirement should be clarified and rewritten in simpler terms.
3.1.2 (pg. 3-3)	The volume requirement for Hygiene, Waste Management, Sleep Compartment and Food Management, as stated on pages 3-3, 3-4, and 3-5.	These are not volume requirements but only summaries of Skylab volumes allocated for each of these functions. There are other functional requirements contained on these pages which are valid for the most part, and may be better suited for inclusion in other sections of this document. These three pages should be re-examined for their applicability relative to the section title and revised accordingly.
3.1.2 (pg 3-10)	Volume Requirements - Doorways	The additional data on doors in Section 3.2.6.2 would fit in this section. Include a reference to Section 3.2.6.2 for additional criteria or incorporate the requirements into this section so all data is centrally located.
3.1.2 (pg. 3-12)	All aspects of airlock design and habitability are critical as emergency and safety items.	What does this mean? This requirement should be clarified or deleted.

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SECTION/PAGE	EXISTING CRITERIA	DISCUSSION/RECOMMENDATION
	ZERO-G HARDWARE DESIGN	
3.2.2 (pg 3-15)	Equipment restraint hardware includes equipment which secures or captivates a given piece of flight hardware.	Change to: Equipment restraint hardware is that equipment which secures or captivates another piece of flight hardware.
3.2.2.1 (pg 3-16)	Provide a means for quick, last minute changeout of labels for stowage nomenclature, restraint, location code, tool usage, and operational instructions.	Delete this requirement from this section. It has nothing to do with restraint techniques and is covered in several places in Section 3.5, Marking and Labels (pgs 3-109, 3-110, 3-111).
3.2.2.1.c (pg 3-23)	The restraints shall be color-coded as a throw-away restraint (see Section 3.5, Marking and Labels).	Reference should be more specific to assist the user. Change to: (see Section 3.5.1, Discardable Items).
3.2.2.1.c	Restraint access and removal by a pressure-suited crewman shall be a design consideration.	Why is this requirement (consideration) only unique to throw-away restraints and not to other restraint techniques. On Skylab, the throw-away restraints were discarded during activation and throughout the mission in an unsuited mode. It appears that this is placing a design consideration upon designers which may be unnecessary.
3.2.2.1.e	Attachment provisions shall be provided throughout the spacecraft for planned temporary restraint usage.	Reword as follows: For planned temporary restraint usage, attachment provisions compatible with the restraint selected, shall be provided throughout the spacecraft.
3.2.2.1.e	Portable devices shall be provided for restraint at unplanned locations.	If it is necessary to have the proper attachment provisions provided at planned use locations for restraints, what sort of attachment provisions can be provided to interface with "portable device" at unplanned locations? This requirement would be difficult to fulfill unless it was established what type of "portable device" would be used exclusively at unplanned locations and some type of interface provided. How would one know what and where to provide them if they are unplanned?
3.2.2.1.e (pg 3-29)		Under LIMITATIONS for Flexible Elastomer Molded Restraint -- Delete "High Weight."
3.2.2.2 (pg 3-30)	Hand Operated Fasteners - Entire Section	Should consider reorganizing this section to make it more positive and restrictive regarding fastener selection.
3.2.2.3 (pg 3-43)	Tool Operated Fasteners - The five (5) requirements, as stated.	All of these are repeats from page 3-30.
3.2.3.4.b (pg 3-48, 3-49)	Attach interface shall be interchangeable throughout the spacecraft.	These are confusing as two separate requirements. Combine as follows:
	Foot restraint receptacles and/or attachments shall be integrated into the floor, ceiling and walls of the vehicle whenever possible	Foot restraint attachment interfaces and/or receptacles shall be common throughout the spacecraft and shall be integrated into the floor, ceiling and walls of the vehicle whenever possible.

There are several instances where various types of restraints are listed as "may be used in conjunction with foot restraints." These are waist, pelvic and thigh restraints but are not specified as a firm requirement in this document. These would fit into an introductory paragraph as possible additions to existing concepts, but based on Skylab experience and post-mission evaluations, may not be necessary.

SECTION/PAGE	EXISTING CRITERIA	DISCUSSION/RECOMMENDATION
3.2.4.a (pg 3-55)	Handholds/handrails shall incorporate simple, quick release attachment techniques capable of installation in many locations.	The attachment techniques have to be compatible with the attachment provisions. Rewrite as follows: Handholds/handrails shall incorporate simple, quick release attachment techniques compatible with installation provisions generously (and strategically) located throughout the vehicle.
3.2.4.a (pg 3-55)	Spacecraft interior hardware generally provide adequate handholds.	This is a valid statement of fact but not a requirement. Incorporate as introductory statement on page 3-57.
3.2.4.3.a (pg 3-60)	A minimum clearance of 50 mm (2.0 inches) shall be provided between the gripping surface and the adjacent mounting structure. This is the minimum gloved hand clearance requirement for pressure suit utilization (see illustration below).	The minimum clearance for EVA handholds/handrails specified in the EVA section, 4.2.1.2 (pg 4-12) is 75 mm (3 inches) standoff and 15 cm (6 inches) grasping surface. These differ from those specified on pg 3-60. Should be resolved.
3.2.5.2.b (pg 3-62)	A mechanical aid, e.g., taut line or rigid boom may be used for convenience to guide large (size and/or mass) items during transfer.	This is primarily an EVA requirement. Recommend reorganization of all transfer methods and devices into internal and external.
3.2.5.2.b	Last requirement states: (See Section 3.2.2.1 for Temporary Restraint Techniques)	There is no such classification of restraints in Section 3.2.2.1 Reference should be corrected to: (See Section 3.2.2.1.e, Multi-purpose On-Orbit Restraints).
3.2.6.2.b	All nonpressurized hand operated internal doors, covers, curtains, and hatches shall incorporate a kickout or breakaway feature.	Rewrite as follows: All nonpressurized hand operated internal doors, covers, curtains and hatches shall incorporate a kickout or breakaway feature for emergency agress. Reference should be made to Section 6.2.2, Escape Techniques and Provisions, for additional requirements relative to this subject.
	STOWAGE	
3.4.4 (pg 3-103)	1. Each stowage module shall be dimensionally configures to be a multiple of the next smallest module. 2. Each stowage enclosure module shall be designed for vehicle installation with minimum vehicle modifications.	This requirement says nothing about what the size or configuration of stowage modules should or shouldn't be. It would seem that minimum/maximums could be given for specific application or at least to offer some concrete guidance.
3.4.4 (pg 3-103)	The three requirements under Nomenclature Location.	These requirements are applicable to Section 3.5, Marking and Labels. These same requirements appear in that section only with a little different wording on pages 3-116 and 3-117, under Location.
	MARKING & LABELS	
3.5 (pg 3-104)		The introductory section, Definitions, is the only part of this document containing definitions other than Section 8.2, where all others appear. Determine if these definitions are required here or if they should be in Section 8.2.
3.5.1 (pg 3-107)	Movable equipment which has an interface with another item shall be identified with nomenclature which aids the crewman in performing a correct interface.	Reword as follows: Movable equipment, which interfaces with other items, shal! be provided with nomenclature to aid the crewman in accomplishing a correct interface.

SECTION/PAGE	EXISTING CRITERIA	DISCUSSION/RECOMMENDATION
3.5.1 (pg 3-110)	Location and Orientation Coding	Dual methods of location and orientation coding were used on Skylab and resulted in confusion. Example: The trash airlock location code number was 634 but in the stowage list it was E699.
	CONTROLS AND DISPLAYS	
3.6.2.1 (pg 3-123)	All displays shall be capable of being dimmed (see also MIL-STD-1472, Paragraphs 5.2.2.1.9 and 5.2.6.6.3). Control and display panels should provide the capability of varying the brightness of each lighting system (e.g., integral, numeric, flood) through the use of an individual control, with the additional provision of a variable one-to-one master lighting control.	Both of these requirements say basically the same thing; therefore, they could be combined into one requirement. The reference to MIL-STD-1472 should be eliminated because it doesn't deal with the capability of being dimmed. Rewrite as follows: Control and display panels shall be capable of varying the brightness of each lighting system (e.g., integral, numeric, flood) through the use of an individual control, with the additional provision of a variable, one-to-one master lighting control.
3.6.2.3 (pg 3-125)	<u>Symbology</u> The meaning of symbols shall be consistent with criteria established in Section 3.5.2.	Cannot find anything in Section 3.5.2 dealing with symbology.
3.6.4.1 (pg 3-127)	The general specifications for controls contained in MIL-STD-1472, Section 5.4.1 are applicable with the exception of the criteria contained in the following: a. <u>Selection</u>: Refer to MIL-STD-1472, Section 5.4.1.1 b. <u>Direction of Movement</u>: Refer to MIL-STD-1472, Section 5.4.1.2 c. <u>Arrangement and Grouping</u>: Refer to MIL-STD-1472, Section 5.4.1.3	The three (a., b., and c) sections listed as exceptions appear to be applicable as general criteria. Do not understand why they are being excepted. Direction of Movement (b.) is more applicable for MSFC-STD-512, Section 3.6.1.2. Consider reinstatement of these -1472 sections.
3.6.4.2 (pg 3-133)	<u>Rotary Controls</u> - As written	There are incorrect reference to MIL-STD-1472 which should be corrected. Should be : 3.6.4.2 <u>Rotary Controls</u>. The criteria below describe: <u>Discrete Rotary Controls</u> (rotates about an axis perpendicular to panel) see MIL-STD-1472, Section 5.4.2.1; <u>Continuous Adjustment Rotary Controls</u> (rotates about an axis perpendicular to panel), see MIL-STD-1472, Section 5.4.2.2; and <u>Thumbwheel Controls</u>, Section 5.4.2.1.3 (rotates about an axis parallel to panel; and are applicable with the following exceptions..........
3.6.4.3 (pg 3-134)	Under example for <u>Pushbutton Keyboards</u>: 2.5 mm (1 in.)	2.5 mm equals .1 in. - Change accordingly.

SECTION/PAGE	EXISTING CRITERIA	DISCUSSION/RECOMMENDATION
	HABITABILITY	
Most of the requirements contained in this section are not applicable to this study, per se. However, there are select sections that do have design criteria directly applicable to Spacelab and Payload Workstation Accommodations. Comments relative to these sections follow:		
3.7.4.1 (pg 3-169)	Odor and Particulate Control - As Written.	The information presented in the table is useful but limited. No time value or exposure rate. (Is this day, total exposure? Are they threshold limit values?) Recommend providing units to values.
3.7.4.2 (pg 3-172)		Relative to the vacuum cleaner, based on Skylab experience, there are a couple of suggestions worthy of retention either as requirements or general information as an introduction paragraph. 1. It was recommended that the vacuum cleaner have more attachments, broader capability and additional power. 2. The vacuum cleaner bags should be planned more carefully based on the Skylab Consumable Summary contained in the Crew Systems Mission Evaluation Report. On Skylab, they had too many bags.
3.7.5.1 (pg 3-175)	The illumination level at the normal washing position in the facility shall be at least 54 lumens/m^2 (5.0 foot candles).	This is a lighting requirement and should be in Section 2.4, Lighting.
3.7.6.2.b (pg 3-184)	Control Approaches and Equipment, #2	Implies that you want to keep the microbial levels at a specific value when they really mean to establish a maximum microbial level.
3.7.6.2.c (pg 3-185) 3.7.6.2.e (pg 3-187) 3.7.6.2.f (pg 3-188)	Control Approaches and Equipment - o Entrapment of Microbiological Contamination o Atmosphere o Stowed Potable Water Supply	Many of the requirements contained in these sections have already been stated in previous sections. With proper document reorganization, these redundancies could be eliminated.
3.7.7.3 (pg 3-192)	First two requirements - as stated. <u>Operational Crew Accessories</u>	Redundant with requirements in Section 3.8.3.
3.7.8 (pg 3-194)	<u>Colors and Finishes</u>	Throughout the text of this section, there are several key sentences that should be listed as requirements rather than general information.
3.7.9 (pg 3-201)	<u>Housekeeping</u>	All of this section is a repeat of previously stated requirements.

SECTION/PAGE	EXISTING CRITERIA	DISCUSSION/RECOMMENDATION
2.4.1 (pg. 2-13)	The first two requirements mention gross activation, casual visual tasks, and gross reading.	Gross activation (1-3 foot candles) and casual visual tasks (3-5 foot candles) have different illumination requirements, but the definition of these terms is unclear. Gross activation could be considered to include equipment activation, installation and moving large objects, which would require higher illumination levels. Also, how do you define gross reading? Better definition or explanation of the tasks relative to these requirements are necessary.
2.4.1 (pg. 2-15)	If the light source is fragile (glass bulb). . . . . etc.	Is this requirement meant to apply to bulk protection to prevent glass particles from floating in the atmosphere or to a cover (hinged) to protect the complete light source? Reference 3.2.1 is unclear--there are no loads directly applicable to light fixtures. Would 3.2.1.a, Dynamic Loads, be what should be used?
2.4.2.1 (pg. 2-15)	A portable light should be supplied that can be easily placed, restrained and accurately positioned leaving the hands free. It should provide at least 300 lumens and maintain its exterior below touch temperature limits defined in Section 6.2.4. The light should be small in profile to provide illumination in small cramped areas.	Shouldn't the 300 lumens requirements be stated in a distance limit of lumens/m^2 and/or foot candles? There is no Section 6.2.4 -- should be 6.2.3.3. Might consider expanding this requirement to include the possible use of a portable head lamp (like the Skylab crews used in the Plenum Area) or a portable wrist lamp. Illustrating the Skylab portable light tends to infer that the light was a good solution -- when in reality it wasn't considered the optimum. Dimensions are missing from the illustration of the portable lamp -- so its size, if small, is unknown. Also, the reference touch temperature is for aluminum, inferring that this is what portable lights will be made of. Should consider rewriting this section to include more design options, attempt to clarify illumination levels, be more specific as to unit size and be more definitive based on Skylab experience and crew recommendations.
2.4.2.3 (pg. 2-16)	Under photography lighting, starting with: The only factor that space . . . . etc.	This information doesn't apply to photography lighting, but to film and film protection which would emphasize the need for a film vault section. This data would fit under a stowage section for items requiring radiation protection (film, mag tape, etc.)
2.4.2.3 (pg. 2-17)	Supplementary illumination for photography in-orbit should be provided.	Change to read: Supplementary illumination for photography in-orbit shall be provided to enhance camera (f-stop, shutter speed) and film (ASA limitations).
2.4.2.5 (pg. 2-18)	Cables over one meter (3.2 feet) in length should have periodic restraint devices to keep the cable contained when in use.	Does this mean that the restraint device should be integral with the cable or that the cable should have provisions to interface with a utility strap? The Skylab crews stated that cable reels as well as more and better tiedowns were needed. Rewrite to read: Tiedowns should be provided for cables over one meter (3.3 feet) in length for restraint, management and to prevent obstructions throughout the vehicle. Consideration should be given to the use of cable reels and cable caddies.

The lighting section doesn't contain any criteria dealing with the requirements for electrical connectors, either as part of this section or via reference to other sections of MSFC-STD-512. Recommend this be considered because electrical connectors are a part of portable light design.

SECTION/PAGE	EXISTING CRITERIA	DISCUSSION/RECOMMENDATION
	EXTRAVEHICULAR ACTIVITY	
4.1.8.4 (pg 4-10)	It should be recognized, if solar lighting is to be used in lieu of supplemental lighting,.....	This is good data for mission planning and operations, but is not a design requirement for contingency task lighting
4.2.12 (pg 4-13)	Handrails/Handholds - As Written.	There is no figure below the paragraph text, but there is an appropriate example below in the example column. Change text to read: . . . . as indicated by the example. Also, raise the example to be directly opposite the corresponding paragraph.
4.2.1.3 (pg 4-14)	Tethers shall be one-hand operable and shall be capable of withstanding a 2046N (460 lbs) working load in any direction. Handrails and handholds should be able to withstand a 556N (125 lbs) working load in any direction.	The Maximum Crew - Induced Design limit loads (3.2.1.c, pgs 3-13 thru 3-15) shows: Tether and attachment 550N (125 lb) Handholds and handrails 550N (125 lb) Foot Restraints 445N (100 lb)
4.2.1.1 (pg 4-11)	Permanently installed foot restraints shall be capable of withstanding a 445N (100 lbs) working in any direction.	For Skylab, the Cluster Requirements Spec (Appendix A) specified higher loads for all external restraints--tethers, tether attach points, handholds and handrails were all 430 lbs. Have the loads for handholds, handrails and foot restraints been reduced for EVA? Has the load for tethers been increased? Should the matrix on pgs 3-13 thru 3-15 be updated to include external aids or are they, in fact, the same as internal aids? Also, the conversion factor for lb.f to N should be consistent throughout (4.45) instead of using 4.4 on occasions.
4.2.2.1 (pg 4-14)	If adequate visibility cannot be provided for crew mounted hardware, guides, alignment marks and/or orientation arrows should be used.	If visibility is less than adequate, alignment marks or orientation arrows will do no good. The following requirements cover the lack of visibility - this requirement should read: If adequate visibility <u>can</u> be provided........
4.2.3 (pg 3-18)	The illustrations for the Skylab Temporary Stowage Hook, Skylab Film Transfer Boom Hook do not fit the requirements for which they are used as examples.	Relocate the examples to fit the requirements.
4.2.6.4 (pg 4-29)	Detail requirements for rotary switches are given and then, in two instances, it is stated that rotary switches are not preferred and should be avoided for EVA use and application.	Should we devote so much space to a negative requirement
4.2.7 (pg 3-40)	EVA lights shall be protected from physical damage and shall have glare shields, when required to preclude glare.	Need to be more specific as to when glare shields should be used. When required is not a sufficient requirement.

SECTION/PAGE	EXISTING CRITERIA	DISCUSSION/RECOMMENDATION
	CREW SAFETY	
6.1.2 (pg 6-3)	Locate connectors, intended for crew operation, far enough apart so that they can be gripped firmly for connecting and disconnect.	These safety considerations are actually general design considerations for connectors. Feel there should be one central location for connectors containing this data.
6.1.2 (pg 6-6)	Crew Operated Connectors Switches and Circuit Breakers - As written	All of these switches are covered in Section 3.6.4.1. Reorganization of the document to have one section on controls and displays rather than three.
	EMERGENCY EQUIPMENT	
6.6.1 (pg 6-26)		Should specify an oxygen supply duration required for emergency breathing. (10 minutes?)
6.3.3 (pg 6-17)	Fire Extinguishing	The Skylab example cited for the fixed fire extinguisher does not meet the requirements established for the fixed fire extinguisher. Removal of the example from pg 6-17 is recommended. Otherwise, the requirements must be changed.
6.5 (pg 6-21)	Caution & Warning Systems	This criteria is logically part of the Controls and Displays Section. Recommend a recombination of the two criteria.
6.8.2 (pg 6-32)	Exposed Corners (Bullet Two)	This statement is really only concerned with exposed corners and the word "exposed" should preface the statement.